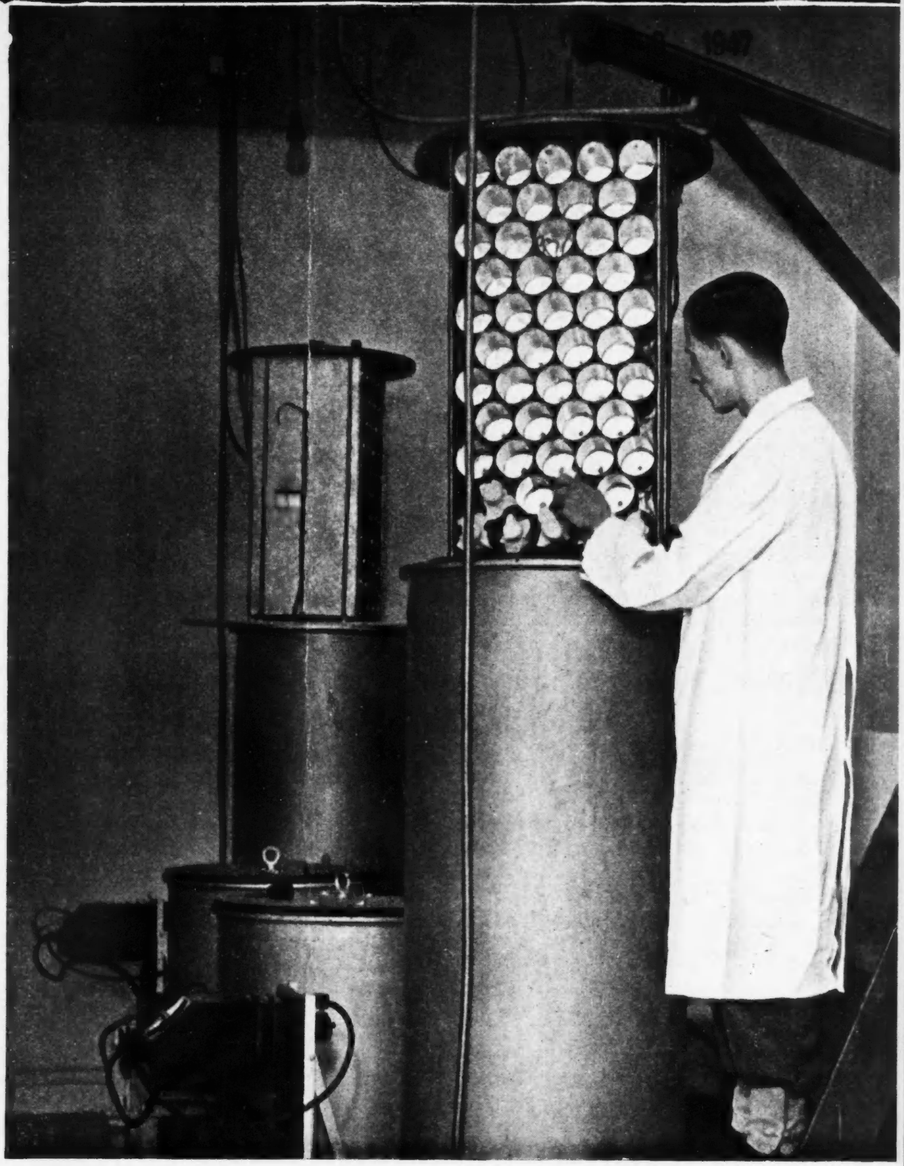
DISCOVERY



MARCH
1947

1/6

The Juni

N contras
esearch d
lemic wor
A sense o
lescriptive
hat appea
f Americ
f a univer
assage is
he young
alary incr
nvitation
eers. . . .
f the 'sla
lossiers, l
ard, their
ations wh
lean desir
o a possib
he empha
The juni
sually emb
roviding s
lucky—i
ear to yea
esearch w
ou will be
ppointme
emonstrat
om one
gain, it is
o specific
esearch w
hat he wh
ext appoi
his next s
uite often
ven a four
Now it i
thers, is u

DISCOVERY

THE MAGAZINE OF SCIENTIFIC PROGRESS

March, 1947 Vol. VIII. No. 3

Editor: WILLIAM E. DICK, B.Sc., F.L.S.
All Editorial communications to
244 HIGH HOLBORN, W.C.1. (Tel. Chancery 6518)
All Subscriptions, Distribution, Advertisements and Business communications to
THE EMPIRE PRESS, NORWICH, ENGLAND (Tel. Norwich 21441)

The Progress of Science

The Junior Scientist's Insecurity

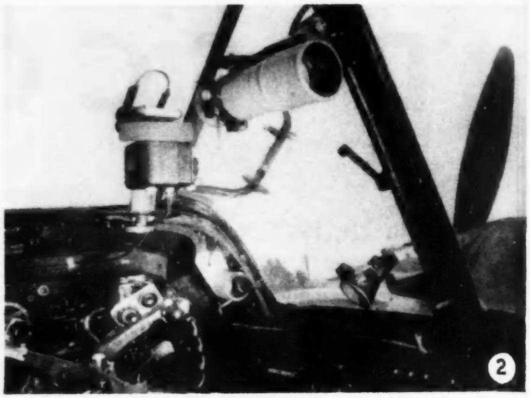
In contrast to the professor who directs the university research department in which he works, the junior academic worker is in a position of great economic insecurity. A sense of this insecurity was cleverly conveyed in a descriptive piece about the meetings of learned societies that appeared in *The Economist*. The writer was thinking of American learned societies in particular, but the aspect of a university career which he illuminates in the following passage is by no means peculiar to America alone. "For the young college instructor, the stepping stone to a better salary increment and a promotion in grade may be an invitation to read a paper before this gathering of his peers. . . . On the bread-and-butter level are the operations of the 'slave market' where many seeking jobs complete dossiers, listing their progress toward the Ph.D. union card, their honours, prizes and awards, and other qualifications which might endear them to the heart of a college dean desiring to add to the lustre of his teaching staff, or to a possible government or business employer—though the emphasis is academic."

The junior scientist, when he has taken his degree, usually embarks on a three-year Ph.D. course, with a grant providing subsistence for the whole of that period, if he is lucky—in many cases the grants have to be sought from year to year. His instructions are "*Finish* a piece of good research work in these three years; if it is good enough, you will be *considered* for an academic appointment." The appointment which is dangled before him is usually a demonstratorship, junior lectureship, fellowship, grant from one of the research councils, or something similar. Again, it is usually tenable for three years. There is often no specific condition this time about finishing a piece of research within three years; but it is clear to everybody that he who does so stands a better chance of that elusive next appointment. With luck the junior scientist may at this next stage obtain a permanent academic post; but quite often he must be content with a third, and perhaps even a fourth, three-year appointment.

Now it is true that this academic worker, unlike many others, is usually free from the threat of sack at a week's or a month's notice (other than for the grossest misdemeanour). But to be set against that short-term security is the fact that in most cases his job has a final dead-line set at the end of three years. The job ends there—whether he gets an appointment to another job (or a renewal of the same one) is an entirely open question. It is usually not decided till within a month or two of the dead-line; often there is a gap of unemployment after the termination of the first appointment.

It goes without saying that this insecurity is very hard on the individual. What is more important to the community is the retarding effect this system exerts on the progress of science. It is true, of course, that the sense of having to find something new at the end of three years may spur on the budding scientist and cause him to burn much midnight oil—whether he will achieve more or less as a result of such hot-house forcing need not be argued. But what is certain is that the three-year threat largely determines the form and content of his scientific work, and is capable of distorting it very much for the worse. The best researches in modern conditions are not planned on a three-year basis; they are planned in terms of ten or twenty years' work devoted to the solution of some major problem or the clarification of some wide field. The best work is done by spending several initial years in mastering a technique (or perhaps a blend of several techniques in order to tackle a new borderline subject), or sometimes even in constructing an apparatus. At the end of those several years the results begin to flow, and the long latent period brings its reward in an even longer period of fruitful productive researches. The period of learning involves something of a gamble, but, other things being equal, the best chance of really great scientific achievements is attained when the initial stages are least hurried, least subject to the need to get something done and published.

The three-year period prevents nearly everybody from beginning a scientific career in this desirable way. The Ph.D. student is compelled by regulation to choose some subject which can be neatly rounded off within his three years; and needless to say he is thus prevented from tackling anything revolutionary. He is forced to take up a problem of the type which fairly obviously requires no



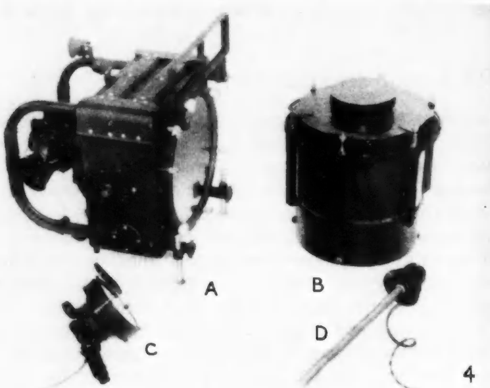


FIG. 1.—A screened infra-red lamp, similar to those mounted on the tails of friendly planes during the war, used in conjunction with the receiver designed for aircraft. This instrument has a range of several miles. FIG. 2.—An infra-red receiver for aircraft identification mounted in a British aircraft. This type was used during the war in fighter operations by the R.A.F. over Britain in 1942. Similar equipment was used for identification of bombers in operations over Germany. FIG. 3.—Two screened infra-red headlamps and adjustable binoculars mounted on a jeep. This equipment was used during the war to allow vehicles to take up position in darkness ready for a dawn attack. The range of the headlamps is about thirty yards. FIG. 4.—These infra-red signalling lanterns and beacons are used in conjunction with the lightweight hand-held infra-red receiver (*A* and *C* are naval signalling lanterns; *B* and *D* are marker beacons).

more than moderate intelligence and hard work to solve. At the next stage he will not have the compulsion of regulations to make him choose a narrow problem, but with his eye on the job which he hopes will follow at the end of three further years, he must inevitably tend to play for safety. The result is that it is only after six or more years of his research career that the young scientist can begin to think about starting on something really of first-class importance. And by that time he has become so used to a succession of narrow and well-defined problems that he may have lost the broad vision required for really deep research. (The occasional geniuses who form exceptions to these statements do not affect their general validity.) It is hard to imagine how much the scientific progress of the world is stultified by this system. We gain, it is true, many dozens of neatly completed Ph.D. theses and minor papers which contribute their little quanta to the sum total of scientific knowledge. But how often do we lose a major advance because we did not allow the scientist to think of such things while he was young and energetic?

When the three-year system was first developed, the idea was perhaps that it would enable the universities to sample rapidly and cheaply the talent of each academic generation, and select therefrom the most promising young men. Sometimes academic authorities seem to retain that outlook even today. Whether the sampling system was ever a good one it is not necessary to consider, for it is certain that today the losses far outweigh the gains. The universities lose directly the quite large number of junior workers who go into industrial research because there they can find sufficient security to enable them to marry and raise families. And the academic world takes a full share of the indirect, but far greater loss arising from the way in which those early hectic spurts based on quanta of three years distort the whole scientific life of each successive worker.

It need hardly be said that the problem is more than

usually acute at present, when the loss of the war years has brought about a situation in which many of the men occupying these junior three-year positions are aged thirty and over.

There does not seem to be any good reason why this systematic insecurity should be continued. Something like the Ph.D. is probably still necessary, but surely it would be possible to change the regulations so that it can be awarded for a good beginning to something big instead of a competent ending of something little. Beyond the Ph.D. stage we do not see any reason why the three-year system should be continued at all, except perhaps for certain special research grants which give exceptional opportunities and can be regarded as competitive prizes. In general, the assistant lecturer, demonstrator or equivalent grade should be appointed for an indefinite period, on the condition that his job goes on until and unless he either gains a promotion, or, by failing to do his work properly, earns the sack.

British Infra-red Equipment

JUST about a year ago we published an item dealing with German infra-red equipment (DISCOVERY, May 1946, pp. 130–2), and in that note we also referred to the use the American Army had made of infra-red. A sequel to the publication of this material was that we heard from scientists who had worked on infra-red equipment for the British Services and who were disappointed that no reference had been made to the British developments in this field. The reason for the absence of any reference to work done in this country was, of course, that the British authorities were not prepared to make available for publication any details about infra-red devices produced for the British Services.

Now, nearly a year later, it is permissible to write about British infra-red equipment used during the war. It is now permissible to say that infra-red signalling lamps contributed materially to the success of the midget-submarine attacks on the *Tirpitz* and Japanese warships, the sinking of the huge floating dock at Bergen in September 1944, cable-cutting operations in Pacific waters, and to more than 100 combined operations from the North African landings to the assault on the Arakan coast.

To Admiralty research scientists who had studied infra-red phenomena since the First World War was given the task of applying for Britain's military use all available knowledge. The production of an infra-red sensitive cell suitable for military use depended on development work carried out in the E.M.I. research laboratories, and this element was used in instruments for the many different applications.

One problem was to supply electric current at a voltage of 3000–4000 volts. The normal system of using a vibrator power unit was developed and used successfully wherever it was possible to accommodate the large weight and size involved; many equipments were supplied with this type of unit. The problem of a 3000-volt supply where lightness and compactness were of paramount importance was more difficult. Early in 1941, the development was completed of a dry pile based on the century-old work of a Swiss priest, Abbé Zamboni, which had not previously had any practical application. The battery, called a

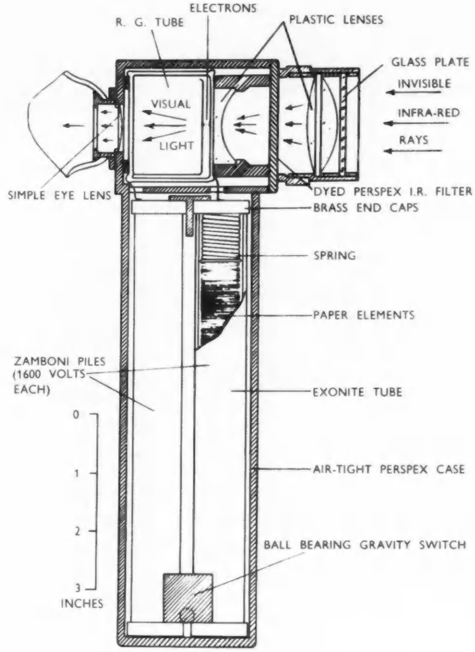


FIG. 5.—Diagrammatic section of lightweight receiver, showing assembly of lenses, infra-red tube and high-tension Zamboni battery.

Zamboni pile, is made from small discs of paper coated on one side with manganese dioxide and on the other with tin-foil. (The method could be used because of the very low current required—less than one-thousandth of a millionth of an ampere.) It is interesting to note that the Germans were developing for the same purpose a miniature Wimshurst machine incorporating modern insulating materials of the polythene-type.

The final infra-red signalling equipment was a small receiver weighing 1¼ lb. with self-contained power supply, which could be operated single-handed with ease. Compared with this the equivalent German equipment—"Seehund"—weighed 16 lb. without its power unit, and was no more sensitive.

First operational use of the new weapon was made in the Mediterranean in mid-1941. In Combined Operations raids infra-red beacons—often small pocket-size torches—and the small hand receivers were used to maintain contact with parent ships offshore. The three midget submarines which attacked the *Tirpitz* in Alten Fiord on September 22, 1943, were given this new weapon. The only craft to return owed its safety to infra-red. Outstandingly successful use of the equipment was made towards the close of the war against Japan. After three operations with midget submarines within a few days of each other—the attack against Japanese cruisers in Singapore Harbour, and the cable-cutting operations at Saigon and Hong Kong—the crews were greatly assisted by using this equipment, and no craft was lost.

Infra-red beacons and receivers were first fitted to night

Alexander Graham Bell.

fighters in the Royal Air Force in 1942. These proved of great value in enabling our fighters to identify each other both in defensive operations and when the night fighters were accompanying our large-scale bomber raids at night over Germany. At a later date, when the bombers were fitted with radar-controlled guns, infra-red equipment was carried by the bombers also, to enable them to identify other friendly aircraft and ensure that fire was opened only on the enemy.

In 1941 infra-red driving equipment was developed to allow transport and armoured vehicles to take up positions in darkness for dawn attack, free from aerial observation. For this purpose infra-red binocular receivers were developed, incorporating two standard infra-red tubes. As a navigational aid during the Rhine crossing in 1945, transport of the 79th Special Armoured Division responsible for ferrying troops to the enemy shore was fitted with this infra-red equipment. Infra-red beacons marked points of the river entry along the river bank.

Another simple receiver was produced to detect possible enemy use of infra-red equipment and extensive infra-red reconnaissance was carried out from the air over enemy lines. Enemy infra-red equipment, however, was never used on the Western front, although its restricted employment was reported during Germany's Eastern offensive.

An infra-red sight for automatic weapons was also developed, but the war ended too soon for it to be used by the British Army.

Alexander Graham Bell (1847–1922)

THE telephone is usually thought of primarily as an electrical instrument. But the main trends that led to its invention by Alexander Graham Bell were acoustical, and on the whole they were connected with the more human side of acoustics—the physiology of speech and hearing, and the teaching of the deaf and dumb.

Most of the special points about Bell's training and early career which fitted him to invent the telephone were acoustical, and even his electrical knowledge arose originally as an auxiliary to his studies of acoustics. Anyone who is teleologically inclined would be tempted to say that all the events of Bell's life and those of his father and grandfather before him were 'designed' to lead up to the invention of the telephone.

Bell was born on March 3, 1847. His grandfather was a professor of elocution, and his father a distinguished authority on vocal physiology and elocution. His father directed his early studies (like those of his two brothers) to the subject of speech and acoustics. He also had a very thorough musical education, part of it at the hands of the famous Bertini. His first researches carried out at the age of seventeen or eighteen while teaching music at Weston-House Academy in Elgin, Morayshire, were concerned with the resonance in the mouth cavities that makes possible the production of vowels. He believed his results to be original, but when he communicated them to a better read friend he was informed that they were contained in Helmholtz's book, *On the Sensations of Tone as a Physiological Basis for the Theory of Music*. He naturally read this work; and in trying to follow how Helmholtz kept tuning forks vibrating by means of electromagnets, he came to realise the inadequacy of his electrical knowledge. Hence we find him in the year 1867 studying electrical science, and naturally in the context of the times his attention was focused in particular on the telegraph and its elements.

In 1870 the Bell family emigrated to Canada, whence Alexander Graham Bell moved to the U.S.A. in 1872. He had already conceived the idea of his 'harmonic telegraph' for the simultaneous transmission of several messages, an instrument demonstrating the combination of electrical and acoustical knowledge in Bell's mind. In his original conception, there are at the transmitting end a number of tuning forks of different pitches, each kept in motion electromagnetically. Each of these is used to produce an alternating current of its own peculiar pitch, which can be started or stopped by the usual key switch. The mixture of alternating currents, each carrying its own message in on-off signals, is sent along the communicating wire to the receiver, and thence to a set of electromagnets to which are presented a set of tuning forks of pitches corresponding to those at the transmitting end. Clearly any one of these last forks will vibrate when, and only when, the corresponding fork at the transmitter is in circuit (the realisation of which fact is, of course, a product of Bell's knowledge of resonance). In principle this is the same as the modern carrier method, though the mode of execution is very different.

The harmonic telegraph in Bell's hands went through a long series of modifications, most of which are not important for our present story. In particular he substituted flat steel tuned 'reeds' for the tuning forks. One form of the instrument, which he conceived in 1874 but never constructed, is important in the evolution of the telephone idea. This was the so-called 'harp apparatus', in which the reeds were to be arranged in a row along the face of a single

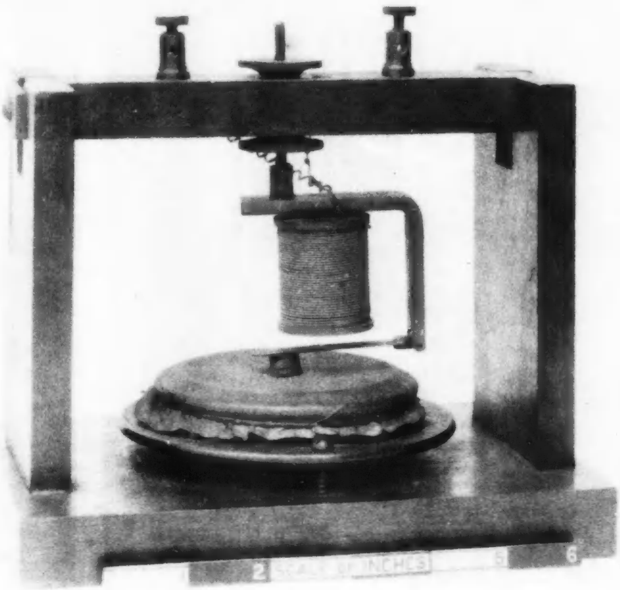
electromagnet, the transmitting and receiving instruments being identical, and the simultaneous signals being as usual separated by resonance.

The 'harp apparatus' is of historical interest because it led Bell to his first idea of a telephone. His knowledge of music and resonance told him that if he sang a note close to the 'harp', the reed of corresponding pitch would vibrate, transmit its current and thus cause the receiver to emit the same note. Furthermore, making use of his knowledge of the harmonic analysis of sounds, he realised that if a complex sound such as speech fell on the 'harp' and if the number of differently tuned reeds were sufficiently large, then all the overtones that go to make up the sound would be transmitted by their appropriate reeds, and the sound would be reconstituted in the receiver. Theoretically this is a telephone, but, as Bell realised, it is an impracticable design.

Meanwhile Bell had continued his work on speech. At many periods in his life he worked on the training of the deaf and dumb; in particular he undertook successfully the education of a certain young deaf-mute, George Sanders—a fact that became of importance later. He was already well known for these activities and for his studies of vocal physiology, and in 1873 he was appointed professor of the latter subject in the School of Oratory at Boston University. In these circumstances it is natural that he should take a very special interest in two new acoustical instruments which came to his notice in 1873–4. In one of these, Koenig's 'manometric capsule', the vibration of a diaphragm under the influence of sound waves was used to control the burning of a gas flame. The flame moves up and down in sympathy with the vibrations, and by looking at it through a rapidly revolving mirror an image of the sound waves is produced. The other instrument was the 'phonautograph', in which the vibrating membrane controls a stylus which scratches a record of the sound waves on a moving plate of smoked glass. Bell had hopes that these instruments would be useful in teaching deaf-mutes to speak—by watching the records, they could check the sounds they produced against the correct version.

He was also struck by the resemblance between the mechanism of the phonautograph and the human ear; this led him in 1874 to investigate the functioning of a human ear taken from a corpse. He used the phonautograph to trace how the eardrum vibrates on receiving various sounds.

Thus by 1874 Bell had three lines of interest relevant to the telephone—the impracticable idea of a telephone based on his 'harp', the two acoustic instruments both of which used diaphragms to convert sound waves into some other form, and his studies of the human ear which again involved a diaphragm. In the summer of 1874 these three trends combined to give him the essential feature of a practicable telephone—a diaphragm which should vibrate, not at any fixed pitch, but in more or less exact correspondence to the sound waves impressed on it, and whose vibrations should be transformed electromagnetically into electric currents.

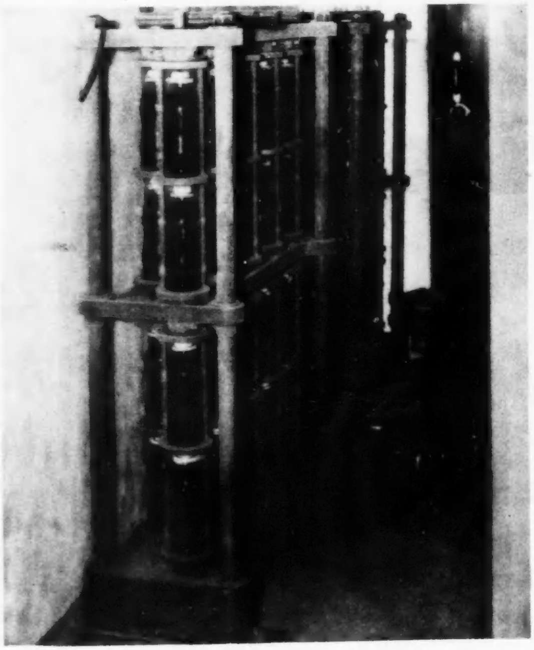


This Bell transmitter represents one of the earliest instruments with which successful speech transmission was obtained. It is very similar to the transmitter exhibited by Bell at Philadelphia in 1876. (*Crown copyright, from an exhibit in the Science Museum.*)

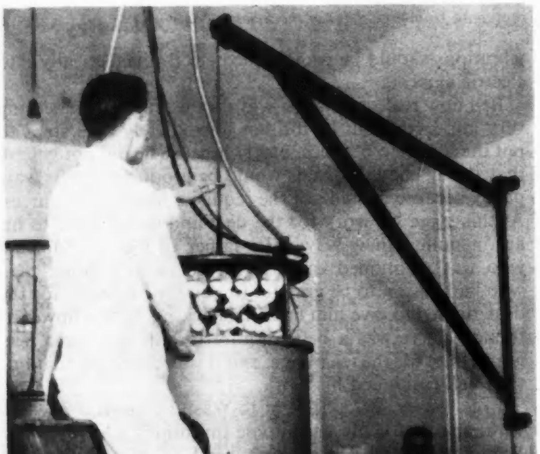
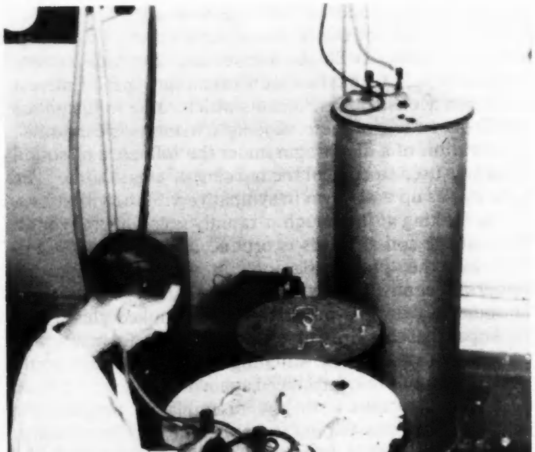
Bell now realised that he was on the track of something very important, but he did not immediately take steps to put the idea into practice, partly because he did not believe that strong enough signals would be produced in this way, partly because he had not the requisite financial resources. At this stage his work for the deaf and dumb came to his aid in quite a new way. The father of George Sanders, who was mentioned earlier, together with another man who had reason to be grateful to Bell for his work for the deaf, agreed to give him financial backing. They, however, thought there was a better future for the harmonic telegraph than for the telephone, and it was chiefly on that line that Bell continued his work.

In February, 1875, he went to Washington in connexion with patents for his telegraphic inventions and there met Professor Joseph Henry, first head of the Smithsonian Institution. Bell tells the story of Henry's reaction to the telephone idea in these words: "He said he thought it was 'the germ of a great invention', and advised me to work at it myself instead of publishing. I said that I recognised the fact that there were mechanical difficulties in the way that rendered the plan impracticable at the present time. I added that I felt that I had not the electrical knowledge necessary to overcome the difficulties. His laconic answer was 'GET IT'. I cannot tell you how much these two words have encouraged me."

Nevertheless, conforming to the wishes of his financial backers, he continued to put his main efforts into the harmonic telegraph, and it was during experiments on that

(*Left*)—First stage is the spin-freezing of the plasma. The bottles here seen in a vertical spin-freezer were actually spinning at a thousand revolutions a minute when the photograph was taken. (*Right*)—By spin-freezing, a hollow cone of frozen plasma is formed in each bottle (see photographs on opposite page).

(*Left*)—After spin-freezing the plasma bottles are transferred to a primary desiccator for an initial dehydration which removes most of the water. Each desiccator of the type shown holds 100 bottles. (*Right*)—The primary desiccator is hermetically sealed with a special wax, and freeze-drying can commence when the pumps connected to the desiccators start working. Drying is completed in a second set of desiccators. The bottles are then filled with nitrogen to prevent oxidisation of the plasma and after sealing they are ready for shipment.

apparatus that the happy accident occurred which showed him how to put his telephone idea into practice. When his assistant, Watson, was attempting to get a jammed reed working again, Bell's superb musical training enabled him to detect and recognise the significance of certain faint sounds that to most men would have passed unnoticed. A day's feverish work by Watson ended in the construction of an apparatus which clearly demonstrated, although again by sounds so faint that only the expert ear could recognise them, that the telephone was a practical possibility. They now concentrated on this line of research, and nine months later Watson had the privilege of hearing the first complete and intelligible sentence ever transmitted by telephone, Bell's voice saying: "Mr. Watson, come here: I want you."

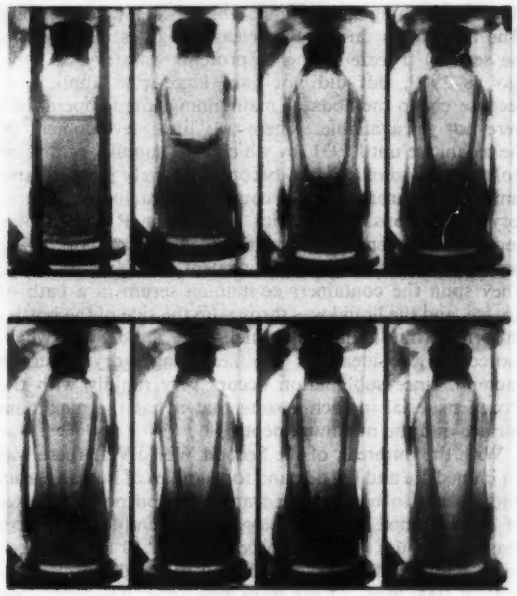
Needless to say, the story of the telephone does not end there. It would not have been an economic success without Edison's carbon microphone. And there were a thousand-and-one other improvements to come. There is the story, too, of how Edison almost forestalled Bell in the invention of the telephone—and much could be learnt by a comparison between Bell's work and Edison's quite different approach to the subject. There is also the rather sordid history of the colossal war over patents, which is very instructive to the student of the exploitation of invention. From all these Bell eventually emerged victorious as the true inventor of the telephone and as the owner of what one judge described as the most valuable single invention of all time.

Such was Bell's social conscience that he paid back his debt to the deaf and dumb, whose troubles had put him on the track of the telephone idea, by devoting much of his subsequent life to helping them. In particular, when awarded the French Government's Volta prize of 50,000 francs, he used it to finance the Volta Laboratory at Washington, which later became the Volta Bureau devoted to the service of the deaf and dumb.

Freeze-drying

THE need to keep meat and fish from going bad meant that man had to try his hand at protein preservation before science as we know it today could assist him, and he gained some proficiency at it long before the word 'protein' was added to the vocabulary. Though it was only comparatively recently that methods of refrigerating protein foods and desiccating them were perfected. The different proteins vary considerably in their behaviour under any particular treatment. A method that proves quite satisfactory for drying one protein food, may spoil or denature the proteins in another. Egg protein, for instance, is more easily spoilt by heat than milk protein. Everyone knows that milk can be boiled without much of the protein content being converted into an insoluble form, whereas at a temperature below that at which milk boils the white of egg coagulates (this coagulation can occur at around 70° C.).

Thus, when it comes to drying milk and eggs on a commercial scale a more refined method is needed for eggs than for milk. Satisfactory dried milk can be obtained by the process called roller- or film-drying; the milk is run on to two heated stainless steel drums that rotate in opposite directions; the milk spreads out as a thin film over the drums and is dried by the heat supplied to the drums by super-heated steam. The temperature to which the milk is raised is high—about 110° C.—and it is only because the high temperature is maintained for a very short time that considerable denaturing of the milk proteins is avoided. As it is, some of the protein is rendered insoluble so that only about four-fifths of the milk powder goes into solution when it is reconstituted. This method is unsuitable for the dehydration of eggs, which are treated by another method, known as spray-drying. The liquid egg is blown as a spray into a stream of hot dry air, whose temperature need not exceed 60° C., and little denaturing of the egg proteins occurs.



Formation of a hollow cone of frozen plasma by spin-freezing. These photographs were taken at intervals of four seconds.

This method was tried for drying blood plasma on the laboratory scale. To avoid overheating and denaturing the temperature had to be kept down to between 70° and 80° C., and the dried product contained too much water to be satisfactory; its storage properties were distinctly poor.

For drying plasma the method which came to be adopted on the large scale is that known as 'freeze-drying'. The plasma is frozen and the ice can be made to sublime when the material is placed under vacuum and can then be carried away by pumping. This sublimation phenomenon is familiar to readers as the one that accounts for the fact that washing will dry even when frozen stiff more rapidly on a frosty day than on a cold damp day.

Freeze-drying was developed for this purpose after attempts had been made to distil off the *water* from plasma and serum under vacuum. This was attempted at the end of the nineteenth century and a dehydrated serum, of rather inferior quality, was obtained; the method was given up because at a pressure low enough to make the process rapid the serum frothed enormously, while at pressures

that kept frothing under control the process was very slow. (The frothing is due to the release of gases dissolved in the serum.) Freeze-drying of proteins was tried as long ago as 1909, but did not gain large-scale application because cheap methods of maintaining low temperatures were not yet available. There was little development of the technique until 1931, by which time supplies of dry ice (solid carbon dioxide) had become relatively plentiful and temperatures around –78° C. could be maintained in laboratory installations. In America W. J. Elser, R. A. Thomas and G. I. Steffen, working at the Mulford laboratories, introduced an important refinement into freeze-drying. They spun the containers containing serum in a bath of dry ice, and the liquid was thrown up the side of the bottles to form a thin liquid shell which froze rapidly and which moreover was ideal for the next stage, drying under vacuum, since sublimation occurs very rapidly with the frozen material in such a state that it has the maximum surface and the minimum depth.

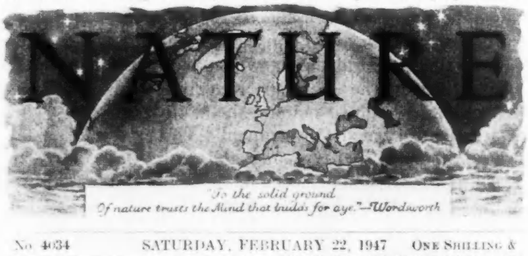
With the outbreak of the Second World War there was an immediate and big demand for supplies of human serum and plasma to be used for transfusion purposes in place of whole blood, which is less convenient for transport reasons, for use by the Services. Where 10 litres a week had been considered a large output of dried plasma, outputs of 1000 litres a week were called for. The first large-scale plant for freeze-drying plasma was developed in America by E. W. Flosdorf, F. J. Stokes and S. Mudd using the Desivac process. This depended on the use of a Stokes diffusion pump large enough to handle all the vapour from ice at a low pressure of 0·1 millimetres of mercury. Such pumps capable of working over the range of pressures between 1 and 10^{-8} millimetres had been developed in connexion with the distillation—'molecular distillation', as it was called—of fish oils to produce vitamin concentrates. The method made it unnecessary to have a cold condenser to act as a trap and hold the sublimed ice as ice. The ice could be allowed to change into water vapour and was carried over in this form into the pump. The difficulty that would arise with a mechanical pump in which the oil would become contaminated with water is not met with here. (In the case of mechanical pumps this difficulty was eventually overcome by passing the oil continuously through a high-speed centrifuge which separated the water from the oil, discharged the water and returned the oil to the pump.) Whereas no condenser was used in this American technique, R. I. N. Greaves and G. S. Adair, working in Britain, developed their method of freeze-drying for plasma on the use of the refrigerated condenser. They found there was no need to use very low temperatures, which are expensive because liquid air is required. With the condenser maintained at about $-40°$ C. by liquid ammonia most of the water could be removed, as ice, from the frozen plasma if the temperature of the latter was kept at about $-10°$ C. With the approach of war the Medical Research Council decided to finance a pilot plant based on the work of Dr. Greaves and his collaborators. This came into operation in March 1940. Then, with the collaboration of the Wellcome Foundation and the refrigeration firm of J. and E. Hall, the Cambridge team was able to build a successful large-scale unit to keep step with the demand for blood plasma from the Medical Corps of the Army and elsewhere. In the final installation at Cambridge, over 300,000 transfusion bottles, each containing the dried product from 400c.cs. of serum or plasma, were produced between February 1943 and September 1945, when the plant closed down with the end of the war in Europe.

The problems met and solved in drying plasma made the use of the freeze-drying technique in later applications such as drying of penicillin much more simple.

The Crisis and Ourselves

It is an understatement to say that this issue was brought out under difficulties. Suffice it to say that 90% of the material in this number had to be set and made up after February 26. We think the rush and hurry has been worth while and we hope readers will think so too. In producing this issue we took comfort from the remark made by Sir Robert Watson-Watt about the introduction of radar devices before they were perfect—"the best never comes, the second best comes too late".

As to the way the periodical press was sacrificed during the fuel crisis, we do not intend to waste words. It was a pity that the Government was not better informed, for had it known how unrepresentative the Periodical Proprietors Association is, it would surely have acted differently. The resentment that has been caused among editors and proprietors of journals who were not consulted—included among these journals are important papers like *The Economist* and *Nature*—could have been so easily avoided. We do not intend to discuss whether the whole affair amounted to a ban on the periodical press or a complete bluff, whether the Government edict sent out by the Central Office of Information was an order or a request for voluntary self-sacrifice, whether or not it could have been enforced legally by invoking Defence Regulation 55. The best thing that can emerge from this unfortunate episode is a recognition by the Government of the true importance of the periodical press, including the scientific and technical press. During the crisis there was one admirable act, which should not go unnoticed. Our great contemporary, *Nature*, which we missed sadly during the period of the bluff-ban, has come forward with a promise that it will bring out all fifty-two issues during 1947—in other words, not a single issue will be lost. The editors of *Nature* will have their work cut out to fulfil this promise, but they will have the satisfaction that comes from the carrying out of a public service, something which is inseparable from good journalism.


NATURE

"To the solid ground
Of nature trusts the Mind that builds for aye."—Wordsworth

No. 4034 SATURDAY, FEBRUARY 22, 1947 ONE SHILLING &

The only weekly periodical that did not lose any issue —any printed issue—was *Nature*. The number for February 22nd was brought out without delay after the crisis.

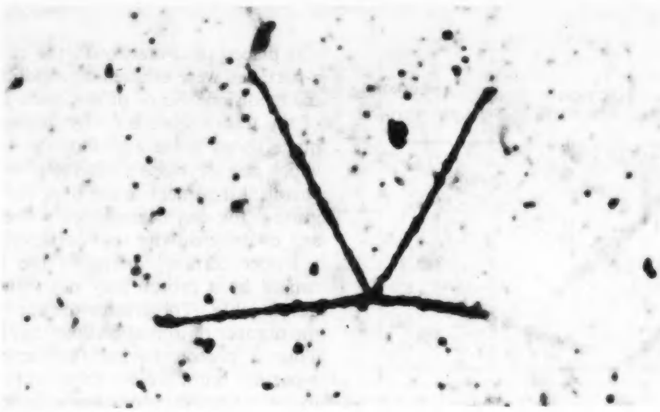


FIG. 1.—New types of photographic emulsion have been developed to aid the study of atomic particles. This thorium star made up of the tracks of four particles into which radiothorium disintegrated was obtained with one of the latest types. See also Fig. 12. (*Courtesy, Kodak Ltd.*)

The Photographic Plate in Atomic Research

R. H. HERZ, Dr. Phil.Nat., F.Inst.P., F.R.P.S.

AT the present time thousands of workers are engaged in laboratories all over the world on the problems of harnessing atomic energy. Many of those problems involve the study of the fate of the particles that are combined in the nuclei of atoms, and to this study methods of detecting fast atomic particles are therefore very important. Many methods have been devised for detecting such particles and in this article details are given about one of the more recent developments, that of recording particle tracks in photographic emulsions.

To facilitate appreciation of the merits of the photographic method it is worth reviewing briefly the other principal detection methods employed in nuclear physics.

Scintillations. One of the simplest procedures of detecting α-particles (helium nuclei) and fast protons (hydrogen nuclei) is to observe microscopically the flashes of light or *scintillations* produced on fluorescent screens when these are hit by fast particles. As each individual particle causes a flash of light on the screen, which is made up of zinc sulphide crystals, the number of scintillations can be counted and the length of path of the particle (i.e. its range in air or other gases) can be measured. The scintillation method was used in the pioneer researches of Lord Rutherford and his collaborators and led to the first observation of the transmutation of nitrogen into an isotope of oxygen by bombardment with α-particles.

Electrical Counting Methods. In electrical counting methods, use is made of the fact that fast charged particles remove electrons from the atoms of gases through which they travel. An atom which has lost an electron and has thus a surplus of positive charge is called a positive ion. If an electron attaches itself to another neutral atom a negative ion is formed. These processes are called ionisation. One apparatus—the Geiger counter—for counting single particles consists of two electrodes, one of which may be a cylinder and the other a fine wire along the axis of the cylinder; both are enclosed in a glass or metal envelope filled with gas at a low pressure. A voltage is applied between the electrodes, high enough for a single ion to initiate a cumulative ionisation process, thus causing a relatively large current pulse. This pulse may be amplified to produce a click in a loudspeaker or to operate a counting mechanism. The Geiger counter is the most sensitive instrument for detecting atomic particles.

The Wilson Cloud Chamber. Another powerful instrument, and one which gives a visible picture of the paths of fast atomic particles in gases, is the Wilson cloud chamber. When a charged particle passes through a gas, a very large number of ions are formed along its path. In the Wilson cloud chamber, a closed vessel containing air saturated with water vapour is so arranged that at any desired time a sudden expansion of the air volume can be produced by means of a piston. As a result of the expansion, the air cools down and becomes supersaturated with water vapour. If a particle has passed through the chamber just before the expansion, water droplets collect on the ions and the track of the atomic particle takes the form of a trail of fog which is clearly visible through the glass wall of the chamber. This track can be photographed, and the cloud-chamber camera can be so arranged that a photographic record of the track is automatically made at each expansion of the chamber. By using two cameras, stereoscopic photographs can be obtained and the path of the particle in space can be investigated. This method has proved valuable both for the study of the fate of individual particles during their passage through the air and for evaluating their properties. In this way sudden changes in the direction of particles due to collisions with atomic nuclei have been observed and important conclusions about the collisions have been made.

The fact that the photographic plate is able to record the passage of fast atomic particles travelling through the

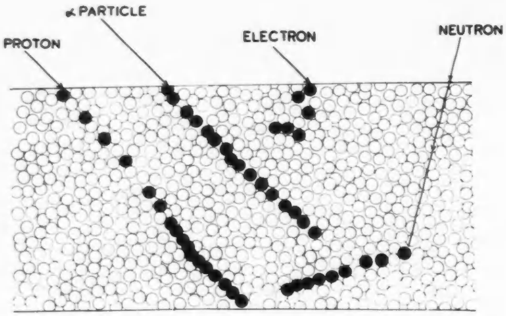


FIG. 2.—Diagrammatic section through a photographic emulsion showing the passage of alpha particles, protons, electrons and neutrons through the emulsion. Empty circles indicate unexposed silver bromide grains, black circles indicate grains made developable due to the impact of atomic particles.

photographic emulsion has long been known. The photographic method was, however, long regarded as inaccurate and restricted to a very limited range of investigations, but the recent development of suitable photographic emulsions, together with a closer study of the method, initiated chiefly by Dr. C. F. Powell of Bristol University, has revealed its usefulness for a great variety of investigations. The chief advantage of the photographic plate is that it is continuously sensitive, whereas the Wilson cloud chamber is sensitive only for the fraction of a second immediately preceding the expansion.

Characteristics of Various Particle Tracks

Alpha-particles and protons. It was first shown by Kinoshita in 1909 that when α-particles impinge upon a fine-grained photographic emulsion they make developable each silver bromide grain along their path through the emulsion. After development of the plate, the track of a particle can be seen when the plate is viewed through a microscope. This track is represented by a linear succession of developed silver bromide grains, as shown diagrammatically in Fig. 2; this figure illustrates the characteristics of the tracks of various types of particles.

The nature of the track depends on the number of ionisations the particle causes per unit length of path, since the chance that a grain is made developable depends on the number of ionisations it receives. An α-particle with its charge of two elementary units and its mass of four units causes many more ionisations per unit length of path than, for example, a proton of the same energy with its single charge and unit mass. The intensity of ionisation produced by an α-particle is more than sufficient to render developable all the silver bromide grains it traverses. A photomicrograph of α-tracks in a photographic emulsion is shown in Fig. 3. This picture, which is a photomicrograph of a very small area of the photographic emulsion, was obtained by exposing a plate to α-particles emitted by polonium, the last-but-one radioactive member of the radium family. The polonium source consisted of a small piece of copper foil, one centimetre in diameter, bearing an electrolytic deposit of polonium on its surface. This was placed in contact with the emulsion surface and the α-particles were emitted at random in all directions into the emulsion. Some of the black dots in the surrounding of the tracks are caused by the background veil which is made up of those grains of the silver bromide emulsion which are developable without exposure. With suitable chemical treatment of the plate before exposure this background fog can be removed without the emulsion losing any of its sensitivity to α-particles.

Under certain conditions the number of ionisations caused by a proton may not suffice to make each grain developable. The greater the speed of a particle, the less the number of ionisations per unit length of path it causes. Thus a proton having the same initial energy as an α-particle but a greater speed will cause so few ionisations in individual grains of silver bromide that not all the grains at the beginning of the track will be made developable. This is the reason for the wider spacing of the grains at the beginning of the proton track in Fig. 3. It is this characteristic which enables the nuclear physicist to distinguish between α-particle and proton tracks in the photographic emulsion.

Deuterons and Tritons. Deuterons and tritons are particles with the same charge as the proton but with twice and three times the mass respectively. The deuteron (H_1^2)

FIG. 3 (*top*).—Photomicrograph of alpha tracks distributed at random in a photographic emulsion. (Magnification approx. 500 times.) The alpha rays were emitted from a polonium source. FIG. 4 (*bottom*).—Photomicrograph of a proton track. The characteristic of this track is that it shows wider spacing between grains at the beginning of the track and closer spacing between grains at the end of the track on the right of the picture. (*By courtesy of Kodak Ltd.*)

is the nucleus of deuterium (the isotope of hydrogen popularly known as 'heavy hydrogen', which combines with oxygen to yield 'heavy water') and it contains one proton and one neutron. The triton (H_1^3) is the nucleus of another hydrogen isotope, and it contains one proton and two neutrons. Because of the greater masses of H_1^2 and H_1^3 the number of ionisations they cause per unit length of path is greater than that of protons, but smaller than that of α-particles, so that the spacing of grains in deuteron- and triton-tracks is roughly intermediate between that in proton- and α-particle tracks. Because the grains are not spaced with perfect evenness, it is, however, rather difficult at present to discriminate between the tracks of deuterons, tritons and protons.

Neutrons and Electrons. The neutron is one of the most important particles in nuclear physics, being one of the building stones of atomic nuclei. It has zero charge and a mass almost equal to that of the proton. As it has no charge, it causes no ionisation and has no direct effect on the photographic emulsion. When, however, a neutron makes a head-on collision with a hydrogen nucleus (i.e. a proton) the proton is knocked on and acquires nearly 100% of the neutron's kinetic energy. Suppose, for example, the neutrons travel through a layer of paraffin; hydrogen atoms are abundant and from their nuclei recoil protons are ejected and these can be recorded in the photographic plate. The gelatine of a photographic emulsion, like paraffin, contains plenty of hydrogen atoms, so neutrons impinging upon the photographic emulsion will also cause proton recoils within the emulsion layer, as indicated in Fig. 2. The photographic plate can thus be used for measuring doses of neutrons.

Although electrons cause ionisation, and undoubtedly bring about a blackening of the photographic emulsion, actual electron tracks have not been observed so far in photographic emulsions. This is partly due to the fact that electrons are about 1800 times lighter than protons and are therefore scattered along zigzag paths in the emulsion (*see* Fig. 2). In addition, the ionisation per unit length is much weaker than in the case of protons. Another difficulty is the background of fog grains, which makes it impossible to the observer to distinguish the grains made developable by electrons. The method of reducing fog mentioned above makes the emulsion insensitive to electrons.

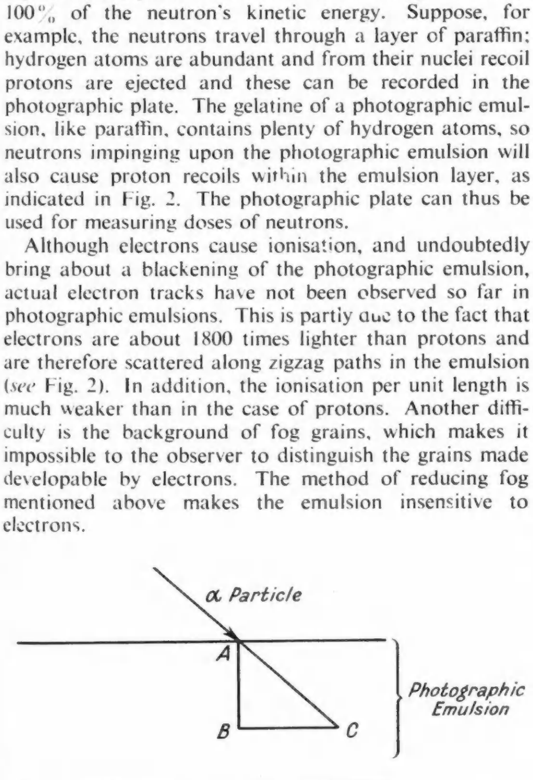


FIG. 6.—Measurement of length of track.

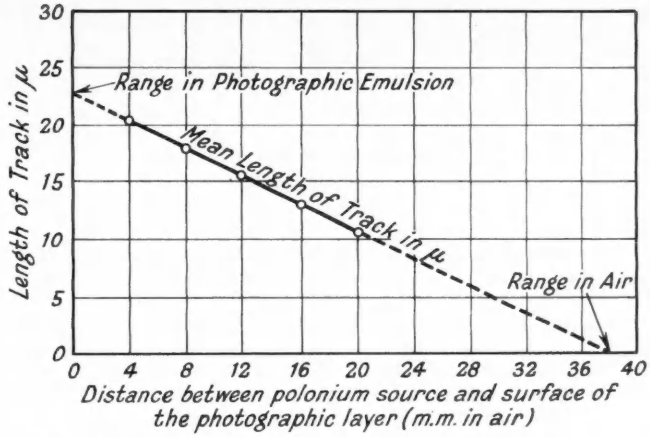


FIG. 5.—Length of polonium alpha-particle tracks in a photographic emulsion as a function of the distance between source and surface of the photographic layer. (After Michl.)

Photographic particle-tracks not only provide information about the type of particle recorded; they also permit the measurement of the energy of the particles and of their angular distribution within the emulsion. Moreover, the yield of certain nuclear reactions can be determined.

The pioneer work of Rutherford and his collaborators provided us with the knowledge of the ranges in air of the α-particles emitted in the radioactive decay of most of the natural radioactive substances. There exists a well-established relationship between the energy of a particle and its range in air. Hence, by firing α-particles of a known range into the photographic emulsion a range calibration for the particular emulsion in use can be made. This may be done very easily with the α-particles emitted by polonium. Polonium has the advantage over most radioactive substances that it emits practically only α-particles. If one places a polonium source at increasing distances from a photographic plate and measures the length of the tracks obtained, it is found (*a*) that the number of silver grains produced in a track is directly proportional to the length of the track, and (*b*) that the range in air of an α-particle emitted by polonium (3·8 centimetres) corresponds roughly to 20–25 μ (1 μ = 1 micron = a thousandth of a millimetre) in a photographic emulsion. (Fig. 5.) The range of an unknown α-particle in air can therefore easily be determined by the use of a correction factor.

If a particle enters the emulsion obliquely, as shown in Fig. 6, the actual distance it travels (*AC*) is greater than the apparent distance travelled (*BC*); the angle of incidence and the true length of the track can be found. The projected length (*BC*) of the image of the track is measured under the microscope by means of an eyepiece graticule calibrated in microns. With high-power magnification two settings of the depth screw of the microscope are obtained, one to bring the first grain (*A*) near the surface of the emulsion into focus and a second to bring the last grain of the track (*C*) into focus. From the depth (*AB*) and the projected length (*BC*) the actual length can be calculated by Pythagoras' theorem. An elementary trigonometrical calculation enables one to determine the angle of dip. By a suitable experimental arrangement the particles can be

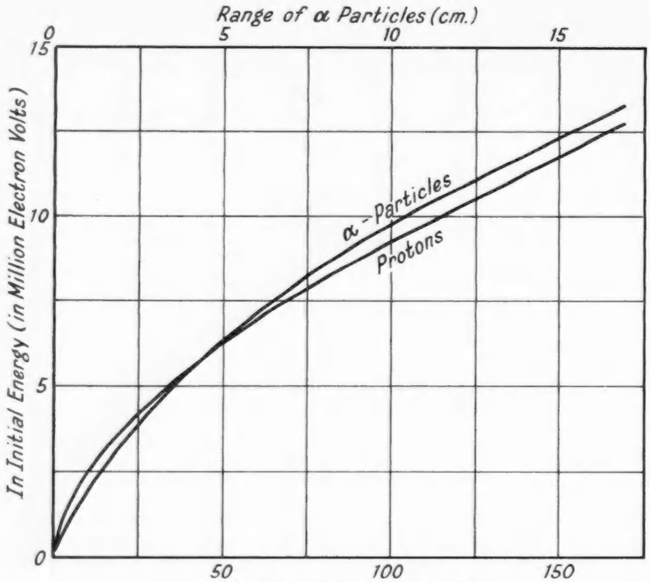


FIG. 7.—Relationship between range (measured in centimetres in air) and energy (in million electron volts) of alpha particles and protons.

fired into the emulsion at a known angle. From the measured length of a particle track the energy of the particle can be determined from the well-established relationship between the energy of the particle (measured in million electron volts, Mev) and its range in air. This relationship is shown in the graph (Fig. 7), for α-particles and protons respectively. It can be seen from this graph that for the same energy a proton has about ten times the range of an α-particle. An α-particle emitted by polonium having a range of 3·8 centimetres corresponds to an energy of 5·3 million electron volts.*

Particle Yield. In many nuclear reactions it is of importance to know the yield of the reaction. It may be known, for instance, in an experimental arrangement how many neutrons per second are incident on unit area of the photographic emulsion. By counting the number of proton recoil tracks per unit area in the developed plate, the yield —the ratio of the number of recoil protons to the number of incident neutrons—can be evaluated. Hence the probability of collisions can be determined.

The experimental set-up to obtain photographic particle tracks is quite simple. It requires no elaborate apparatus, apart from the powerful generators to produce high-speed particles such as the cyclotron and high voltage generators, though natural radioactive substances may often be employed instead. How the apparatus is set up for the exposure depends chiefly on the particular problem to be solved, but generally a simple arrangement, such as the one shown in Fig. 8, is useful for the study of a great variety of nuclear reactions. The incident particle beam impinges upon a sample of an element (E) and the reaction of these particles with this element may be studied. The resulting particles may be stopped by a mica window to a known extent and are then passed through a diaphragm into the actual camera and on to the photographic plate, the angular position of which with regard to the direction of the incident particle may be varied and measured by a protractor. If necessary, the chamber may be evacuated by means of a vacuum pump. Some of the reactions can be carried out with radioactive substances instead of a powerful cyclotron or high-voltage generator, in which case the experimental set-up can be simplified. The yield and energy of particles emitted by radioactive material is, however, very limited, and only a restricted range of reactions can thus be studied.

Specialised Photographic Emulsions. The photographic emulsions employed in the past have suffered from the disadvantage that the separation of the silver bromide grains was rather great, causing wide gaps between the grains of a track. The accuracy with which the length of the track could be measured was therefore rather small, since it was often difficult to recognise where the track began and ended. A great improvement came with the introduction of new plates (in the first place by Ilford Limited) having a high concentration of silver to gelatine. As the grains are very closely packed, the track lengths can be measured accurately and hence energy determinations based on track lengths are accordingly more reliable. A comparison of α-particle tracks in an earlier and in a concentrated emulsion is shown in Fig. 11. For the recording of particles which enter the emulsion at larger angles with regard to the plane of the emulsion, very thick emulsions up to 300 μ thickness have been used.

Some Applications

A few applications of the photographic method may give the reader an idea of the powerful tool into which this method has developed.

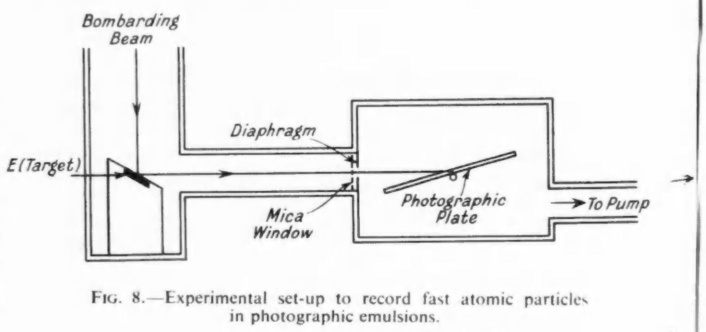


FIG. 8.—Experimental set-up to record fast atomic particles in photographic emulsions.

* It is usual to measure the energy of nuclear particles not in terms of ergs but in electron volts, i.e. the energy that an electron acquires in falling through a difference of potential of 1 volt.

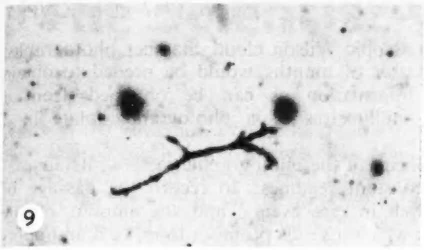
problem to
le arrange-
Fig. 8, is
variety of
rticle beam
ent (*E*) and
this element
rticles may
o a known
ugh a dia-
d on to the
position of
ion of the
d measured
he chamber
a vacuum
be carried
nstead of a
e generator,
t-up can be
of particles
s, however,
ed range of

sions. The
in the past
ge that the
grains was
between the
h which the
efore rather
where the
came with
ce by Ilford
to gelatine.
ack lengths
determina-
ore reliable.
er and in a
the record-
rger angles
very thick
d.

ethod may
into which

→ To Pump

les



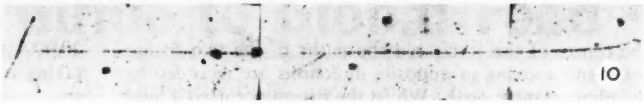


FIG. 9.—Multiple nuclear recoil produced by fission fragment from uranium. FIG. 10.—Uranium fission track (*left*) and probably alpha particle track corresponding to 22 Mev particle emitted in uranium fission. The photograph is a mosaic of three photomicrographs. (*Courtesy, D. L. Livesey and L. L. Green, Cambridge.*)

Fig. 12 shows in each star-like image the α-ray emission of a single atom of radiothorium, when it disintegrates into its various daughter elements. This photomicrograph was obtained by bathing a photographic plate for ten minutes in a solution of thorium nitrate. After drying the plate in the dark, it was kept in a light-tight box for one week and was then developed. Inspection of the plate under the microscope revealed hundreds of star-like images, such as those shown in Fig. 9. Each arm of a star represents a track of an α-particle ejected from one of the various decay products of radiothorium and thus illustrates the radioactive decay of this element. The decay products thoron, thorium A, thorium X and thorium C′, which emit the various α-particles in succession, are indicated (for the left-hand bottom star) in the diagrammatic figure at the left of Fig. 12. Only α-particles are recorded on the plate, since the electrons and gamma-rays emitted in this radioactive disintegration do not leave recognisable tracks in the emulsion. The identification of the various arms as corresponding to a particular decay element is done by measuring the lengths of the tracks. The photographic method also permits the study of the decay of very weak radioactive substances, as it was recently done with the element samarium by Lattice and Cuer, who found long-range α-particles emitted by this element.

Successful experiments have also been made to load the emulsions with elements (such as boron and lithium), in which nuclear reactions are to be expected when exposed to high energy particles. Recently nuclear fission tracks were obtained in this way by D. L. Livesey and L. L. Green, of the Cavendish Laboratory, Cambridge. They soaked the photographic plate in a solution containing uranium atoms and exposed the plate to low-speed neutrons using a lithium-deuteron-neutron source. The fission tracks obtained by Livesey and Green are shown in Figs. 9 and 10. The fission track in Fig. 10 is the short track seen on the left of the photomicrograph. The fission occurs near

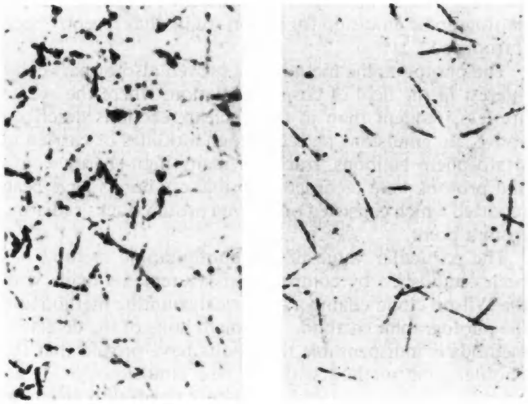
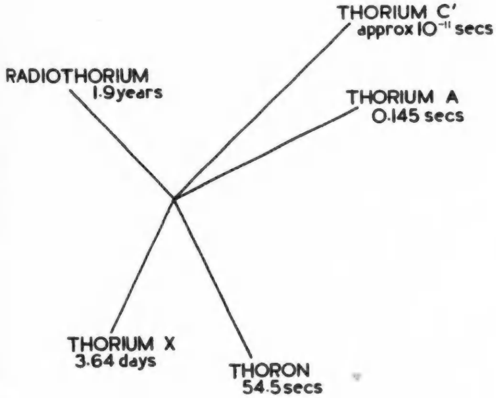


FIG. 11.—Comparison of alpha tracks obtained in older type and in new atomic-particle plates. (*Courtesy, Kodak Ltd.*)



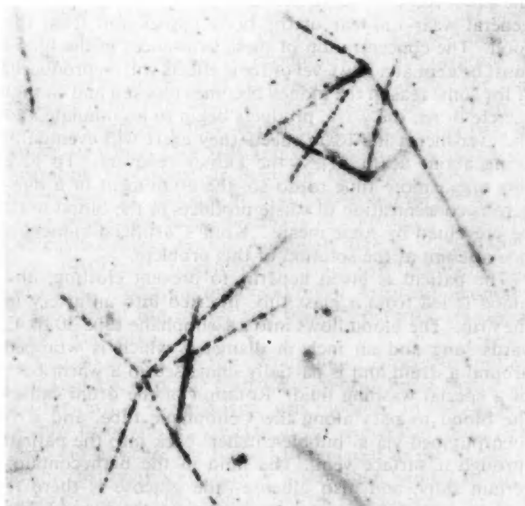


FIG. 12A (*right*).—Thorium star showing the alpha radioactive decay of radiothorium. FIG. 12B (*above*).—Identification of tracks and half-life times of elements from which the particles are emitted. (*Courtesy, Kodak Ltd.*)

the centre of the track and the paths of the two fission fragments moving in opposite directions are recorded by the photographic plate. Whilst the fission occurred a light charged particle, probably an α-particle of unusual length corresponding to an energy of 22 million electron volts was emitted, as shown in the long track expanding to the right of Fig. 10. Fig. 9 shows multiple nuclear recoil produced by fission fragments from uranium. The nuclear recoil is probably due to silver or bromine atoms from the photographic emulsion. The recording of fission fragments presents specific photographic problems; a special Kodak photographic emulsion for fission studies has recently been introduced.

The photographic method has proved also of particular interest in the field of cosmic radiation, where the events are less frequent than in the nuclear reactions described above. In emulsions placed at high altitudes or carried in stratosphere balloons, tracks of many high-energy α-rays and protons were recorded. Cosmic-ray bursts have been reported which consisted of a dozen proton tracks radiating from a point.

The particular value of the photographic method has been established by comparing measurements made with the Wilson cloud chamber, electrical counting method and the photographic method. Although none of the detection methods is indispensable the results have proved that the photographic method with the new emulsions yields an accuracy of the same order as is obtained with electrical counting devices. In specific problems as many as 10,000 to 20,000 stereoscopic Wilson cloud chamber photographs, taking a matter of months, would be needed to obtain the same information as can be obtained from a few square millimetres of a photographic plate in a few weeks.

The simplicity of the photographic method, its adaptability, its constant readiness to record the passage of particles (even in rare events) and the amount of the information which it yields promises to make it an important tool in the study of nuclear physics. Its development appears to be still in its initial stage. Whilst this article was being written, newspaper reports were published about new uranium fission experiments in which fission into three and four particles was observed and these discoveries had been made by means of the photographic method in Professor Joliot's laboratory in Paris.

Much of the development of the photographic method is due to Dr. C. F. Powell and his collaborators at the University of Bristol. In a recent lecture to the Royal Photographic Society in London Dr. Powell suggested that nuclear physics would be a suitable subject for amateur activities in which these could contribute to the knowledge of nuclear physics by use of a relatively simple method as that described in this article. Similar activities by amateur astronomers are well appreciated. Rare events in nuclear disintegration phenomena which can be studied only by observing many thousands of tracks under the microscope could be revealed by industrious amateurs who might be proud to contribute to this subject.

An Artificial Kidney

A DUTCH medical scientist, Dr. Kolff, and his colleagues have recently made an 'artificial kidney'. This device, prepared from Cellophane, was intended for use in serious cases of kidney failure, where the problem is to keep the patient alive until his own kidneys have recovered. The chief function of the kidney is to remove continually from the blood certain waste products which derive from the general wear-and-tear of the body tissues and from the food. The concentration of these substances in the blood must be kept at a low level or toxic effects will be produced. If for some reason the kidney becomes blocked and cannot secrete urine, the waste products begin to accumulate and the ever-increasing toxic effects they exert will eventually bring about death unless the kidney recovers. To give this organ more time to do so, the attainment of a dangerous concentration of waste products in the blood must be prevented by some means. Kolff's 'artificial kidney' is one attempt at the solution of this problem.

The patient is given heparin to prevent clotting, and blood is led from a glass tube inserted into an artery in the arm. The blood flows into a Cellophane tube 30 to 45 yards long and an inch in diameter, which is wrapped around a drum and is partially immersed in a warm bath of a special washing fluid. Rotation of the drum causes the blood to pass along the Cellophane tube, and it is then pumped via a 'bubble-catcher' back into the patient through a surface vein. The fluid in the bath contains certain salts, and also glucose—the glucose is there to stop water diffusing from the bath into the blood. The Cellophane tube contains about a pint of blood and this passes through the apparatus in about four minutes, so a large volume of blood can be dealt with in a few hours.

As the blood flows through the Cellophane tube, the waste products of the body's metabolism pass through the Cellophane into the bath, while red and white corpuscles, blood proteins, and the like are retained. This process of separation is called dialysis, and was discovered by the chemist Graham, who found that substances could be divided into two classes termed 'crystalloids' and 'colloids'; crystalloids pass through a membrane such as parchment paper or an animal bladder, but colloids do not, and Graham discovered that compounds of the two classes could readily be separated by this means. Fortunately, most of the substances which it is desired to remove from the blood behave as crystalloids.

The apparatus certainly removes appreciable quantities of waste products from the blood. For instance, with one patient, 263 grams of urea were removed from the circulation in one dialysis. In the normal subject, the kidney removes about 30 grams of urea a day and keeps its concentration in the blood at about 0·015–0·03%—equivalent to about 1–grams in the whole circulation.

Out of the first twenty-five cases treated, only five survived, but it must be realised that the 'artificial kidney' was only used on patients whose chances of survival were considered to be practically nil. Dr. Kolff believes that some of the others would also have died but for the help of the 'artificial kidney'. On the other hand, apparently hopeless cases have been known to recover unaided in the past and so it is difficult to assess the value of the treatment at present.

The Scientist's Guide to Global Food

F. E. LE GROS CLARK, M.A.

When in the 'seventies, Europe (and more especially our own country) began to feed an increasing population upon reserves drawn from overseas, both the soils and in some measure the labour of distant territories could be exploited for the production of cheap food. That has become less possible. Soils have been wastefully exhausted or are subject to erosion; and in the last decade the problems of soil management have been raised to the level of a top priority. At the same time farmers, plantation labourers and their governments are demanding what they call a fair price for their products and a stability of prices, which will mean that the consumer gains but transitory benefit from a price slump on the agricultural market.

The quantity of food that has thus been entering the world market is, of course, very small in relation to all the food that is produced and consumed. It amounts in normal times to less than 10% of the total. But it assumes for us a disproportionate importance. For Europe as a whole it is less significant; Europe, with her comparatively stable soils, her equable climate and her reserves of farming labour, could increase and diversify her farm production to a remarkable extent. The main tendency, in fact, is for the world trade in food to contract rather than grow. This may appear paradoxical at a time of continued scarcity; it is nevertheless true The more important and perhaps the more realistic section of the latest report from the Food and Agricultural Organisation,* is concerned with the correlated development of industry and agriculture in more backward countries or groups of countries. The field for scientific application lies here rather than with the complex problems of exportable surplus and world price stabilisation.

In one sense the report is a withdrawal from an earlier position. The months that have passed since the Copenhagen Conference last autumn have infused into FAO a measure of caution. It scarcely claims now to be an operating body, that is a body that can command funds sufficient to enable it to buy and sell, to accumulate and unload stocks of any magnitude. What it is in process of becoming is a 'world brain' on all matters concerned with the production, the distribution and the consumption of food and other products of the soil and the seas. As a brain, it is at the disposal of any country that cares to make use of it. It can advise (and its recent report on the problems of agricultural development in Greece shows that it can adv[illegible] effectively) upon such matters as fertiliser requirements, the disposal in industry of surplus farm populations and the location of useful processing plants. So much to the good. But there are difficulties. In the nature of things much of the available supply of specialists and research workers has to be drawn from the United States and a few of the Dominions. In the case of the Greek survey a large proportion of the working team was American. The ability of such a team to come to grips with the problems peculiar to the country under investigation is beyond question. They were scientifically trained observers; and they made their contribution. But we cannot avoid the fact that, in the present state of the world, foreign specialists are suspect in a number of countries.

Let us, in the light of the report we are considering, examine a little more closely the evident conflicts and divergencies of interpretation, that are now beginning to emerge in FAO. The U.S.S.R. is not yet a member nation. Why not? The answer may be complex, but, in my view, one reason is that FAO has in its growing pains to determine whether and how far it becomes in effect an instrument of American policy. No international organisation can remain suspended in a limbo of good intentions. Its specialists, its funds and its main trends of policy have to be derived from one or more of its member nations. As matters now stand, both the specialists and the funds of FAO are likely to be derived to a disproportionate extent from the United States; and any steps taken to carry out the FAO proposals on the holding of famine reserves, the retention of 'buffer stocks' of primary foods and the disposal of surpluses to necessitous countries, could be contemplated only by the United States and a few of the countries that fall more or less under American influence. The proposals are applicable only to those overseas countries that, from the seventies of last century, became the large reserve food sources for the supply of the European markets.

There is no suggestion in the latest FAO report that anyone should control the accumulated stocks of food except the countries that produce them; that might have been anticipated. The scheme is otherwise a commendable attempt to solve, in part at least, the vexatious problem of farm surpluses. The only difficulty lies in its political implications; and this, it must be admitted, is a serious one. There is, as far as the U.S.S.R. is concerned, nothing very attractive about a scheme that merely seems to teach the large food-exporters how to use their spare stocks to the highest political advantage in the international field. Thus, whether it be the intrusion of Anglo-American specialists into backward economies or the disposal of American surpluses among hungry populations, the fact remains that *at the moment* the proposals of FAO affect mainly American policy, because there is no other field of policy to which they will apply. If a team of specialists operating in Greece or Siam or Peru recommends the investment of money in soil conservation or hydro-electric schemes, there is scarcely any prospect of finding the capital except on the American market. Objectively, then, FAO in its search for solutions can find them only through a special accommodation of American economy to the rest of the world; and that is where the resistance begins to emerge.

It seems clear from the comments of American spokesmen that the original plan for a World Food Board, as put forward at Copenhagen, was modified in the interval mainly through the objections of American delegates. They did not care for funds to be placed in the hands of an international agency, over whom there would be little or no control. They considered that widespread government intervention would have a detrimental effect on the

* *Report of the Preparatory Commission on World Food Proposals*, Stationery Office, 1*s*. 6*d*.

supply and demand situation for food products; and they believed (perhaps with justification) that the price system proposed would be unworkable without some control over supplies. Particularly were they explicit that the problem of poverty could only be approached through a general expansion of production, employment and trade; and this for them was a matter especially of trade expansion. Now it is at this point that doubts may arise, not merely in the U.S.S.R. and a number of struggling national economies, but also in some western European countries and elsewhere.

Such countries (and they include our own) are perfectly prepared to negotiate trade agreements in food and raw materials with other countries. But they each want to be free to negotiate whatever agreement seems most useful at the moment, whether through the open market, or by State purchase, or by a long-term contract, or by a barter arrangement, or even on a price basis devised quite outside the level of world prices. No formula for international trading practices will quite fit all these possible variations. It is true that any one of them might have a disturbing effect on markets in other countries, but the major disturbance would be felt not so much between a few of the smaller countries but by the large food-exporting countries. In other words, we have here a conflict of interest between the struggling national economies (which again must be allowed to include our own) and the industrially and agriculturally mature countries that are simply intent upon an open market, wherever and whatever that market may be. This introduces yet a further complication. FAO has mainly been the child of economists in some of the food-exporting countries which are industrially less mature. It has been grafted on to the structure of the United Nations almost by chance and because the minds of so many people were concentrated through the war upon the problem of food. More significant as an instrument of American policy is the projected International Trade Organisation; and what we are now experiencing is in fact the process of making FAO subordinate to the International Trade Organisation.

Nevertheless, the recent report is a valuable document, because it presents a case and argues it. What I have said is a necessary foreword for any scientific worker who wishes to have a clear idea of the conditions within which we are all attempting to get on with the job. The conditions must be viewed objectively. Both the U.S.A. and the U.S.S.R. are presumably obeying the laws of their own internal development; and our own devious path becomes at moments tolerably clear. But there is one further comment that must be made. The catalytic effect of FAO upon world opinion is probably more intense than we can as yet realise. All these reports, in some form or other, are being read and marked by a great diversity of peoples. They are not visions of the night; they are, in fact, the results of hard and precise meditation upon the world's miseries. They could in theory be applied; and the average producer and the average consumer of food in the back-streets and the mills sees no reason on earth why they should not be applied. It is, in brief, as primers of food revolution that the FAO documents may be read. But what form that revolution in its course will take, is a matter beyond our range of prediction.

I began by referring to the seventies of the last century and the early flow of food imports from overseas into the Old World. History has now moved to the inevitable stage, where these large exporting countries seem to overshadow the countries of the Old World. Our own case is a peculiar one, because we are an outstanding example of a trend. We have to pay the price, because we can no longer insist, as we once could, on exploiting soils and men for our cheap supplies of food. If we turn one way, we are caught, in the wash of the American economy. If we turn another way, we find native peoples no longer prepared to work in the same manner and for the same remuneration. We have only one path, and that is the use of science to raise the level and lower the cost of food production in the world. We are still waiting for a purely British version of FAO proposals, and as soon as we can clear our minds and begin to consider our own interests we might secure a document of surprising self-revelation.

THE END OF DAVENTRY 5XX

DAVENTRY 5XX or as we call him in the Engineering Division, the 'Old Gentleman', is about to go into honoured retirement as a museum piece.

It was in July 1925, that a small band of engineers climbed Borough Hill, Daventry, and began to operate what was then the highest-powered broadcasting station in Europe. The National Programme, 1500 metres wavelength and 25 kilowatts into the aerial. Nowadays this would be low power; we normally use four times as much. In fact we possess a transmitter capable of delivering more than thirty times the power of 5XX.

In 1925 we were very conscious of an audience of some 20 million listeners, and much time and enthusiasm went into our efforts to improve our breakdowns—many of them—breakdowns caused by pigeons which seemed to have an odd liking for bare voltage wires; breakdowns by field mice seeking warmth, which were done to death and a cinder by a sudden flash; breakdowns by grass seeds choking the cooling water filters; by silver thaw, which brought the 500-ft. high aerial crashing into the field.

In 1934 the new really high-powered transmitter at Droitwich took over the 1500-metre wave for the National Programme, now the Light Programme, and the screaming generators at 5XX were silent for a while. But the Old Gentleman's day was far from over. Long hours of German propaganda transmissions certainly earned him a medal. For a time 5XX worked on 391 metres, radiating the Home Programme, and after "D" Day he transmitted messages for the R.A.F. In the end, the war needs ceased altogether—5XX had reached the end of the road.

For a time we've kept 5XX as a standby for Droitwich, although a change-over would have been difficult because the 500-ft. masts at Daventry now support shortwave aerials for the B.B.C's Overseas Services.

L. Hotine, B.B.C. Senior Superintendent Engineer, in a Light Programme talk on February 11.

Man's Influence on Marine Life

PROFESSOR C. M. YONGE, D.Sc., F.R.S.

MAN has had a profound effect on terrestrial life. Hunting, first with flint tools and eventually with precise weapons, led to the extinction, for instance of the bear, wolf and boar in Britain and to the almost complete extinction of the bison of North America. Like the big game of Africa, this animal has been saved only by tardy methods of conservation. Fur-bearing animals have been remorselessly trapped. The faunae of the earth have been irreparably impoverished by the senseless destruction of unique birds such as the dodo and the great auk. Cultivation of crops and domestication of animals modified plants and animals so greatly that the exact origin of some is now obscure, and also effected far-reaching changes in the balance of nature. The greater the crops, the more the pests—insects, rodents and birds especially—that were attracted.

With the full discovery of the world by western man, his crops and domestic animals were introduced into the new lands of America, Africa and Australasia, and many of the foreign plants were brought back—accompanied, all too frequently, by foreign pests. Often for sentimental reasons, hosts of other plants and animals were similarly transported. This indiscriminate mixing of fauna and of flora led to disasters such as the plague of rabbits and of prickly pear in Australia, and that of bramble thickets spread by the introduction of the starling into New Zealand. Man, in despair, turned to nature to redress the balance he had wantonly destroyed, and, after some failures, there were developed methods of biological control which today are clearing the prickly pear from Australia and destroying the aphid pests of Californian orchards. But, despite the rigorous care enforced by bitter experience, the spread of life continues. The chance introduction of a malaria-carrying mosquito, *Anopheles gambiae*, from West Africa into Brazil in 1930 caused a terrible epidemic, overcome only after heroic measures by the Rockefeller Foundation.*

Life in the sea has been much less affected by man. In the obscurity of its depths and in the breadth of its oceans animals are difficult to hunt to extinction, while most of the marine vegetation and the bulk of the diverse invertebrate fauna are useless to man. In the sea, it has been said, man reaps without sowing, and this is largely true. It follows that in this case the responsibility of ownership which came with the domestication of animals and the care of crops has rarely displaced the unconsidered greed of the hunter. This is nowhere better shown than in man's pursuit of the marine mammals.

There are three groups of these: the sirenia or sea cows, the marine carnivora such as seals and walruses, and the cetacea comprising the whales, dolphins, and porpoises. The sirenia are a small group of obscure origin and grotesque form. They inhabit inshore and estuarine waters, feeding on marine vegetation. They consisted, until recently, of three groups, the Indo-Pacific dugong, the manatee of the tropical Atlantic, and the much larger northern sea cow of the north Pacific. The first two survive, although actively hunted—fortunately mainly by native tribes—for their flesh and blubber. The sea cow became extinct some thirty years after its discovery in 1741 by the young German naturalist Georg Steller, who accompanied Behring's pioneer voyage to the North Pacific. Under the greatest difficulties, while marooned with unwilling helpers on Behring Island, he dissected and described the animal. The Russian hunters and traders who followed Behring quickly exterminated it, and, apart from Steller's description, there remain for study only a few skeletons. The destruction of the sea cow is the greatest blow yet dealt by man to the marine fauna, equivalent to that of the equally remarkable, harmless and locally distributed dodo.

The walrus once occurred in vast numbers throughout the north Pacific and the Atlantic where it extended as far south as Nova Scotia and occasionally reached the shores of Britain. Following wholesale slaughter, such as that of 900 in one day near Spitsbergen in 1852 and that indicated by an annual import of 12,000 tusks into San Francisco alone between 1870 and 1880, it has become restricted to far northern waters. Many seals have suffered similar destruction, in particular those that breed in rookeries, like the Atlantic grey seal, and also the Greenland seal which is the most important animal in the Newfoundland seal fishery, and the immense elephant seals (Fig. 1). Of these, the Californian species is now rare, but the naturalists of the *Discovery* Expedition found that the Antarctic species, which has been hunted on such a scale that it was reported virtually extinct a century ago, has reached a population of some 100,000 around South Georgia, where hunting is now annually confined to definite regions of the coast. A warm-water seal, once widely hunted in the West Indies, is now extremely rare.

These animals are sought for their blubber and flesh, but the eared seals, or sea lions, include the fur seals as much prized for their pelts as the sable, beaver or silver fox on land. Formerly, various species abounded in northern and southern waters, but in the latter they have been almost exterminated, although there is some hope that they may be re-established in south Georgia. The greatest fishery of all was on the Pribilov Islands in the Behring Sea some three hundred miles from Alaska. These islands were discovered by the Russians in 1786. There the vast rookery, with each huge bull gathering a harem sometimes exceeding one hundred females, and continuously fighting intruding males, must have presented an amazing spectacle. At the hands of Russian and American sealers upwards of two million seals were killed in fifty years. When the United States acquired the islands in 1867, attempts to control pelagic (open-water) sealing in the Behring Sea led to international complications, and so to arbitration by a tribunal in Paris. This was followed by two Anglo-American commissions sent to the Pribilov Islands in 1891 and 1896–7. Eventually, pelagic sealing was prohibited by international agreement, and killing on the islands was restricted to the needs for food of the local

* See "Stowaway Insect Caused 20,000 Deaths," by Dr. G. Lapage, DISCOVERY, February, 1946, Vol. VII, pp. 49–50.

FIG. 1.—A herd of elephant seals on a beach in South Georgia. The figure of the sealer shows the size of the bull. (*Reproduced by courtesy of Dr. L. Harrison Matthews*).

population. Gradually the seal population recovered, and by confining hunting to the males, one bull to forty bearing cows being adequate for breeding, a rational control has been achieved.

It was the Russians also who discovered the delightful sea otter on the coast of Siberia. This rarest and most valuable of fur-bearing animals was hunted ruthlessly from there across the Aleutian Islands and south to California, where British and American hunters were at work. Almost complete extinction was again followed by international protection early in this century. Subsequent recovery has been slow, but populations of some two thousand in northern regions, and two hundred in southern, were estimated in 1939.

Helpless exposure on or near land invited slaughter of sea cows, seals and sea otters. A similar fate has befallen the cetaceans, which include the largest animals ever to be evolved—the blue and fin whales—and which are so superbly adapted for aquatic life that they are even born in the sea. The tragic story of their ruthless hunting by man was begun by the Basques in the tenth century and has culminated in mass destruction by whale chasers operating from great factory ships in the Antarctic.

Man the hunter has thus inflicted terrible loss on the marine mammals; fortunately it has not been worth his while, except in the one instance of the sea cow, to hunt them to final extinction. He has also, with the elaboration of increasingly efficient instruments of capture, made grave inroads into the stock of many of the more important food fishes. Here attention must be confined to the history of the European fishing grounds, in the exploitation of which Britain has played a leading part. The growth of the modern trawling industry dates from that of big industrial towns and the establishment of rapid transport between them and the fishing ports. The first North Sea trawlers came from Brixham in Devon. Originally in open boats, and later in two-masted smacks, the fishermen gradually extended their activities as far as the rich Dogger Bank. Towards the end of the last century, steam trawlers employing the highly efficient otter trawl began to replace the sailing vessels, and to range as far north as the Barents Sea and as far south as Morocco. This wider range was necessary because the fish became increasingly fewer and smaller on the original grounds. Evidence of overfishing was given before a series of Royal Commissions but no action was taken, the extension of fishing to new areas tending to obscure the effects of depletion. Then came the war of 1914–18, which imposed a close season on fishing. The result after the war was striking: fish had increased in both numbers and size. In the period between the wars much of the scientific activity of the Ministry of Fisheries was devoted to working out and testing possible remedies for overfishing. This was the more necessary because as the years passed, the effects of overfishing again became obvious. To take but one example of many cited by Dr. E. S. Russell in his book *The Overfishing Problem*: the landings of haddock per day's fishing by English steam trawlers in the North Sea were 7·8 cwt. in 1906; this fell to 4·6 cwt. in 1914, rose to 15·8 in 1919, and had descended again to only 2·6 cwt. in 1937.

One obvious method of control is to enlarge the mesh of the vast trawl nets which annually sweep over practically the entire productive surface of the fishing grounds. This would enable the smaller fish to escape for further growth, and possibly reproduction, before capture. Another, more far-reaching, measure is to limit fishing. This demands a wide knowledge of the natural reproductivity of the fish. Unlike the marine mammals, with their annual or biennial production of one calf, fish produce vast numbers of eggs annually, of which only a few reach maturity. Food, though abundant, is not infinite, and growth is checked owing to intense competition. In other words, a certain degree of fishing is definitely helpful. It reduces competition and enables more fish to attain a large size. But clearly too intensive fishing has the reverse effect. It is a question of knowing exactly how much can be taken out with safety, so that man may obtain a rich harvest without adversely affecting natural stocks. It is actually not only more economical to fish with fewer vessels but the yield may in fact be greater than if too many are employed and the effects of overfishing produced.

Despite the size and obscurity of the fishing grounds, the basic fact concerning the productivity of the chief north Atlantic food fishes are known. This is due to the labours of the scientific staffs of the English and Scottish fishery services and those of the other maritime countries of western Europe. All normally work in close co-operation through the International Council for the Exploration of the Sea. It is now possible to formulate measures of control which, when aided by continuous scientific supervision, will permit a rational exploitation of the fishing grounds. How successful such action may be is well shown by the result of treaties made between the United States and Canada in 1924 and 1930, and renewed in 1937, for the control of the Pacific halibut fishery, in which both countries are interested. An international fisheries commission was set up, and the fishery, which had undergone catastrophic decline, has recovered to a striking extent after limitation of fishing. In such rapid recovery we see the result of the great fecundity of fish. Populations of whales or seals may take a century to recover fully after too intensive hunting; those of fish will recover in a much shorter time.

Today, after the second close season imposed by war within a generation, there is clearly an opportunity for conserving the now well-stocked fishing grounds of western Europe. The British Government is certainly of

this opinion. At its invitation an international overfishing conference was held in London not long after the end of the war. Representatives of all the maritime nations of western Europe except Germany attended, and considered the possibility of agreeing on measures for regulating fishing in the North Sea and adjacent areas. With the needs of starving populations constantly in mind far-reaching decisions could hardly be expected, but agreement was reached on an increase in the size of the mesh of trawl nets and also on size limits for the twelve most important bottom-living food fishes. Limitation of the tonnage of the fishing fleets of the different countries, which was proposed by Great Britain, was not accepted, but the reality of the problem of overfishing was realised to the extent that an advisory committee was appointed to study the matter and propose suitable regulations for the prevention of overfishing in the North Sea and adjacent areas. There is thus some real ground for hope that in the future the fisheries of Europe may, like those of the north Pacific, pass from an era of over-reaching greed to one of rational exploitation based on conservation of the stocks.

Aquiculture, or the cultivation of aquatic life, has been conducted on a very limited scale compared with agriculture. With the exception of some cultivation in Japan of seaweeds from which agar is obtained, it is, moreover, restricted to animals. Its greatest, and by no means negligible, triumph has lain in the cultivation of oysters and other bivalves.

The aim of aquiculture is to increase some part of the population, either in numbers or in size of individuals. This may be done by improving their chances of survival, by transplanting them to regions where food is more abundant, or by increasing the fertility of confined waters. Although there is evidence that the Romans practised crude methods of oyster cultivation in Lake Fusaro and elsewhere, modern cultivation may be said to date from the work of Costé on the French oyster beds. These one-time prolific areas became progressively more depleted as a result of increasing demands from the growing industrial cities during the middle of the last century. Costé realised the fundamental fact that the oyster produces immense numbers of free-swimming larvae, but that only a minute fraction of these find the requisite clean, hard surface for settlement when they sink to the bottom. From his suggestions and experiments arose the modern method of putting out 'collectors', consisting of half-cylindrical roofing tiles encrusted with lime and sand, in the early summer, when the oysters are ready to spawn. In this way millions of oyster 'spat' find surface for settlement. Costé further realised the need for protection. After some months of growth, the young oysters are flaked off the tiles and transferred to *ambulances*, where they are protected by wire netting from their numerous enemies such as crabs, starfish, rays and marine snails. Later still the oysters are laid out on extensive parks, from which intruders are removed at low tide. Today, the vast area of these parks around the shallow, almost land-locked bay of Arcachon, and in other regions of the French coast, are evidence of a flourishing industry. The French also found that oysters would grow and 'fatten' in areas where they will not necessarily breed, and began to transplant oysters into shallow lagoons or *claires*, particularly around Marennes. In these warm waters the microscopic suspended plant life, or phytoplankton, on which the oysters feed, increases rapidly. By such methods a highly organised and immensely productive oyster industry has been built up along the Atlantic coast of France.

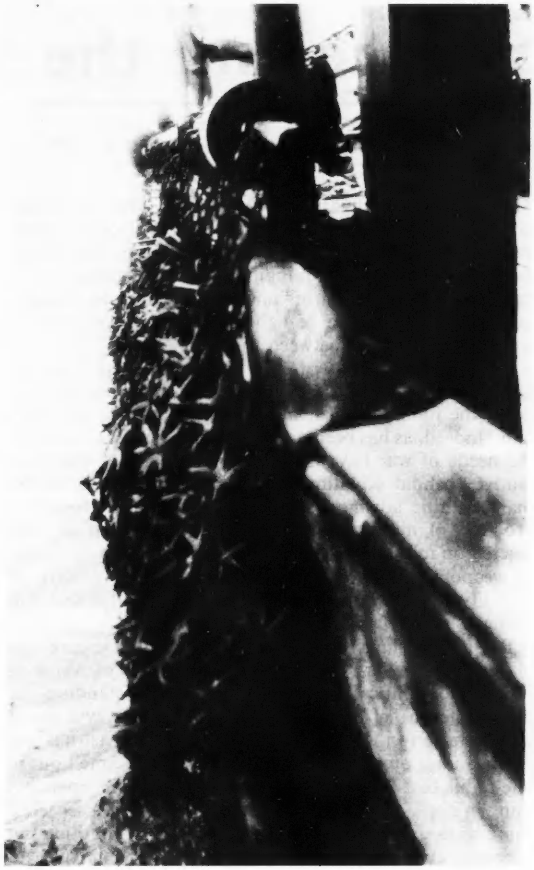


FIG. 2.—Starfish collected by tangles from American oyster bed.

Similar methods, involving provision of settling surface, removal of pests, and transplantation to better feeding grounds, have been developed in many other countries, especially the United States. In the Delaware River, for instance, a natural breeding area some distance up the estuary is maintained, and a collecting surface in this case consisting of masses of clean oyster shells spread loose or in wire-netting bags, is provided. These shells are later dredged up, the young oysters separated, and a proportion laid on planting beds nearer the sea, where they rapidly grow. The beds are regularly swept with wide spreading cotton tangles (Fig. 2) in which the invading starfish are collected in millions, while continuous warfare is waged against other pests. The output of this one oyster fishery runs into some four hundred million annually.

This article, which is reproduced from the last issue of ENDEAVOUR *by permission of the Editor, will be continued in our next issue.*

Science and the Evolution of War

E. M. FRIEDWALD

"THE necessity of fighting very soon led men to special inventions to turn the advantage in it in their own favour: in consequence of these the mode of fighting has undergone great alterations. . . Fighting has determined everything appertaining to arms and equipment, and these in turn modify the mode of fighting; there is, therefore, a reciprocity of action between the two."

In these few words written more than a century ago in his monumental work, *On War*, Carl von Clausewitz laid down the fundamental relation between science and warfare. Indeed, as has been pointed out in a previous article,* the needs of war have always provided one of the main motives behind scientific pursuits, and it is safe to say that scientific advances in the past have often been by-products of military technique. This science in its turn reacted on military technique; it conditioned the evolution of weapons, means of protection and, more recently of mobility—that is, the three most fundamental material elements of warfare.

But in changing the technique of warfare, science has played a major part in altering the character of war as a social and political phenomenon. Notwithstanding the deep-rooted belief of well-intentioned idealists, war is not an aberration in the life of mankind—or at least has not been so until our own time. As Clausewitz pointed out in one of his best-known passages, war is not an independent thing in itself. Considered as such it would be "a senseless thing without an object". But in fact "War is nothing but a continuation of political intercourse with a mixture of other means . . . a policy, but no doubt a policy which fights battles instead of writing notes . . . which takes up the sword in place of the pen, but does not on that account cease to think according to its own laws."

This concept has remained true throughout the ages. But to what extent does it still hold good today? How far can an atomic war be regarded as a political act, let alone a political instrument? For have we not seen two World Wars in which the victors have lost hardly less than the vanquished and, far from reaching their political objects, have unwittingly brought about a state of affairs contrary to their policies? And this happened in wars fought with weapons, the destructive power of which was but a minute fraction of that of the weapons we now know. With the prodigious rise of science, and its unlimited application to warfare, can war any longer be controlled by policy? Does not its destructiveness defeat its own objects? This is the great reality of the twentieth century: that war has ceased to be an instrument of policy, and has become "a senseless thing without an object".

The Pre-technological Era

Yet the transoceanic range of the aeroplane or the rocket and the cataclysmic striking power of the atomic bomb are but the culmination of an evolution which has been going on throughout the ages. Ever since the beginnings of organised warfare, which historians trace back to the Battle of Marathon in 490 B.C., man has sought to improve his tools of war along the same lines, always aiming at greater range of action, greater striking power, greater volume of fire, greater accuracy of aim and greater mobility. But in the past this evolution was extremely slow, simply because scientific progress capable of influencing weapons, means of protection and mobility was so slow. From the dawn of classical warfare until the introduction of gunpowder into Europe at the beginning of the fourteenth century, the sword, the spear and the bow and arrow were the mainstay of warfare.

No doubt these were not the only tools of war; there were other weapons of a more evolved technical character. We know of the engines invented by the scientists of Alexandria in the third century B.C., among them a kind of machine-gun for firing arrows, and catapults operated by compressed air. We also know of the engines for throwing projectiles which the Romans used three centuries later. There was a definite tendency towards the mechanisation of war in Caesar's time. The Byzantines possessed a peculiar and extremely effective weapon known as 'sea-fire' or 'Greek fire', a mixture inflammable on contact with water; this mixture whose exact composition is unknown was projected by means of a siphon and ignited by a cross-jet of water. It was in fact a crude flame-thrower, which enabled the Byzantines to ward off for several centuries Moslem and Russian attempts at invasion by sea. Lastly there was the marked improvement of missile weapons in the latter part of the Middle Ages, the bow giving place first to the cross-bow in the eleventh century, then to the long-bow towards the end of the thirteenth century. But both were only perfected forms of the bow. However, all these devices—with perhaps the single exception of sea-fire—were no more than trivial additions to the basic instruments of warfare.

During this period there were marked changes in the character of war; the citizens' wars of the Greeks and the Romans were succeeded by the peoples' wars of the fourth century, and after them came the medieval wars of chivalry which were a trial by battle limited by the rulings of the Church. Yet these changes do not seem to have arisen from weapon development, for the basic instruments of war remained the same throughout. In fact, the West deliberately shunned the bow and arrow, the symbol of cunning, in favour of the sword and the spear, the symbols of valour. It was the conception of war which dictated the choice of weapons, and not the weapons which dictated the conception of war. It was only the use by the English of the long-bow towards the close of the Middle Ages which, by defeating the knight, began to undermine valour and to put a premium on cunning, thus paving the way for the transition from idealistic war to realistic war, from the age of valour and chivalry to the age of technology.

* See "Science and Political Power", DISCOVERY, October 1946.

Gunpowder—the beginnings of Technology

In the history of war and politics, the introduction of gunpowder into Europe is one of the most important landmarks, for it inaugurated the era of technology in warfare and that of power in politics.

Yet in tracing the link between social and political developments and changes in military technique, it would be an over-simplification to ascribe the downfall of the feudal system entirely to the discovery of gunpowder and the invention of firearms and artillery. It was probably the rapid expansion of money economy and the rise of capitalism which, more than any other factor, broadened the recruiting basis and laid the foundations of permanent and professional armies, thus cutting at the roots of medieval society. Firearms and artillery were not the cause of these developments, but they were undoubtedly a most important contributory factor, because they accelerated the evolutionary tempo. It was artillery which battered down the feudal castle and so destroyed the very basis of the feudal system; just as it was the development of portable firearms which mercilessly drove out the knight, and democratised fighting by placing a most powerful weapon in the hands of the common soldier.

At the same time the invention of gunpowder and firearms worked in favour of the stronger power and against the weaker. For only the very wealthy were able to afford the heavy cost of artillery and of equipping large numbers of soldiers with portable firearms. Power thus became concentrated in the hands of the prince who consequently gained ascendancy over the Church. By the same process the whole character of war changed: from being a trial by battle limited by the rulings of the Church, war became an instrument of political power. Machiavelli was the first to recognise this change. He saw that war had ceased to be a chivalrous contest and had become a struggle for survival and that, therefore, the employment of all possible means was permissible in war. No consideration of justice or injustice, humanity or cruelty, pride or shame should be allowed to interfere with the prosecution of such a struggle. Machiavelli—who also advocated conscription —was the prophet of modern war as well as the first military thinker of modern Europe. He saw the new forces and sensed the new technology which were to transform the feudal state into the bureaucratic and absolutist state —a very slow process which did not reach its climax until the eighteenth century.

Similarly, the changes in the character of war due to the introduction of gunpowder did not come about all at once. The period of adaptation of firearms lasted for two centuries, from the fall of Constantinople, when the cannon revealed itself as the dominant weapon, until the end of the Thirty Years' War. This was one of the most troubled periods of history, and the invention of gunpowder was one of the main causes of the strife. For history shows that great political upheavals are apt to follow great advances in the realm of science and technology. Such a crisis seems to have confronted Europe as a result of the introduction from Asia of the horse and the sword in the second millennium B.C. The introduction of gunpowder and the invention of firearms, coinciding as they did with the great religious schism, produced somewhat analogous results. The crisis reached its climax in the Thirty Years' War—a total war unsurpassed in savagery since the wars of peoples of the fourth century.

These very horrors produced the salutary reaction—a tacit understanding to restrict the evils of warfare in accordance with common sense and self-interest. The century and a half following the Peace of Westphalia is known as the period of professional armies and dynastic wars. On the whole these wars were 'limited' wars, perhaps not so much by their limited objects as by the limited means with which they were fought. The fact that there was no radical change in the technical sphere during that period was probably not without influence in this respect. But to an even larger extent this limiting of warfare by a generally accepted code was the outcome of a conception born of that respect for reason which was the creed of the eighteenth century. All this, however, was swept away by the flood of the French Revolution.

Industrialisation of War

The fact that the French Revolution occurred in the midst of the Industrial Revolution has somewhat confused the issue as to which of the two was responsible for the great changes which took place at the turn of the eighteenth century. This remark is particularly applicable to the transformation that occurred in the character of war, i.e. the transition from dynastic to national wars, from limited to unlimited warfare, from clashes of professional soldiers to the destructive struggles between peoples. Most military historians, among them Jähns and Delbrück, attribute this change to the new political and social forces brought to life by the French Revolution. Some, like General Colin, look for a more material explanation, and find it in the technical progress achieved through the Industrial Revolution. However, this latter view is not supported by historical fact. For the Revolutionary and Napoleonic Wars, which were peoples' wars, at least on the French side, were fought more than a generation before the Industrial Revolution* could make itself felt to any marked extent in the realm of warfare.

The new form of warfare made, in fact, its appearance even before the French Revolution. For the War of American Independence was ideologically and materially the first manifestation of the Nation in Arms. And it is significant that Clausewitz's philosophy of absolute warfare was born well before the progress of the Industrial Revolution impinged upon the sphere of warfare. In his work, *On War*, which was written between 1816 and 1831, Clausewitz insists a great deal on the imponderable and non-material forces in warfare, but takes little account of the material forces, especially of what might be called the technical factor.

But if the French Revolution was the soul of unlimited warfare, the Industrial Revolution was its body. For without steam power, total war in the modern sense of the word could not have come into existence. War underwent mutation in the century that saw the half-million army of Napoleon replaced by the five-million army of the Third Republic, with twice as many men and women

* It was not until 1807 that the first steam-boat made its way from New York to Albany, nor until 1830 that the first railway service opened between Manchester and Liverpool; as late as 1820, the world output of pig-iron did not exceed the million-ton mark.

working behind the lines in direct support of the armed forces. It was not until the railway made possible the mobilisation and movement of armies of millions that the concept of the Nation in Arms could become a reality. Nor until the tremendous increase in fire-power—through the development of the repeating rifle, the machine-gun, and quick-firing artillery in the second half of the nineteenth century—could the 'absolute' war of Clausewitz materialise.

Perhaps no less potent in shaping the character of the new warfare than these purely technological developments were certain trends in the realm of scientific thought. At first sight it might seem odd to connect a purely scientific hypothesis with political developments. Yet Darwinism had a profound influence on the evolution of war as a social phenomenon, for it provided a scientific support for Clausewitz's philosophy. Indeed, the 'struggle for existence' and the 'survival of the fittest' as expounded by Darwin represented scientific recognition of the existence in nature of a counterpart to what Clausewitz had found to be effective in the more restricted field of international conflict. It is hardly surprising that in a scientific age faith should clutch blindly such a support offered by natural science.

Prototype of 'Total War'

It was only two years after the publication of *The Origin of Species* that the American Civil War broke out—the first *guerre de matériel*, and in many ways the prototype of the modern 'total war'. And there is no doubt that, apart from the totality of its object—("This Government cannot endure permanently half-slave and half-free"), the new means provided by technology contributed to a large extent to giving the war this total character. Here for the first time strategic use was made of the railway on a large scale. It meant a revolution in warfare, the extent of which can be judged when it is realised that, throughout previous history, land mobility had been bound by the limits of the human or animal leg. Quite apart from the use of railways which made possible the employment of mass armies, the American Civil War was characterised by an extraordinary burst of inventiveness in the technological field. It produced or saw the first trial of armoured ships, railway artillery, telegraphs, balloons, machine-guns, repeating rifles, hand grenades, land mines, submarine mines, torpedoes, trenches, wire entanglements and even a primitive form of the submarine. Among the few who saw the significance of this great drama was Karl Marx, who in 1867 wrote in the preface to his *Capital*: "Just as the American War of Independence in the eighteenth century sounded the tocsin for the middle classes of Europe, so the American Civil War has sounded the tocsin for the European working class." Marx as well as Engels understood the immense influence that science and technology exercise on the methods of warfare, and thus on the character of war. The industrialisation of warfare led directly to total war. Thenceforth, it was to be waged not only, nor even mainly, on the battlefields, but in factories, on farms, and to an ever-increasing extent in laboratories.

But the same forces of science and technology which were laying the technical bases for total war were at the same time rendering war a questionable instrument of policy, though this was scarcely realised at the time. On the one hand the tremendous increase in fire-power immensely multiplied the power of the defensive, threatening to drive armies into trenches. Under these conditions, war between Great Powers was bound to bring slaughter on an unprecedented scale and a long-drawn-out stalemate, ruinous both in human life and wealth, in which the ultimate decision was more likely to be reached by blockade than by any feat of arms. On the other hand, under the impact of the railways, steamships and the telegraph, the economic relationship between nations was undergoing a complete change. Nations which formerly had been economically self-sufficient and self-contained units were becoming more and more dependent on each other. The separatism of the pre-industrial age was giving place to what has been called 'the global situation', the growth of economic interdependence with a growing solidarity and community of interests. Now war, long drawn-out as it was bound to be, was certain to interrupt the functioning of this global system and thus to destroy the basis on which was built the prosperity of all concerned. Furthermore, a protracted war fought with the total resources of whole nations, was likely to drain the wealth, both human and material, of the victor scarcely less than that of the vanquished. And on top of that the victor, in the interest of his own prosperity, would have to undertake the task of rehabilitating the vanquished.

Indeed, all this was made abundantly clear by the 1914–18 War and its aftermath. In spite of the tremendous exertions on the battlefields, the issue was decided by blockade. France, the victor, never recovered from the loss of her two million men, nor Britain from the loss of her economic and political power. In many respects Germany, the vanquished, lost the least, to a large extent because Britain and the United States, believing that their prosperity depended on that of Germany, lost no time in rebuilding the power of the defeated. The world's loss was the disappearance of the global system with its community of interests which existed before 1914 and which failed to return after the war.

And so the question arose, What political objects could justify such high stakes? Were not the risks out of all proportion to the possible gains? Were not science and technology transforming war from a profitable business into a self-inflicted bankruptcy? At the beginning of the century, Mackinder had already pointed out that there was nothing eternal about British sea-power, that mechanical transport was endowing land-power with greater mobility and altering the relative strength of sea-power and land-power, an evolution which the advent of the submarine accelerated. Sea-power was on the wane, and land-power in the ascendant. And land-power is vastly more destructive than sea-power; it tends to promote unlimited war, while sea-power is the ideal instrument of the limited form of warfare.

Now it must be borne in mind that, technologically, the war of 1914–18 was but the culminating point of the age of steam, the crowning achievement of the Industrial Revolution. The aeroplane and the radio were still in their infancy, robot warfare still belonged to the realm of Wellsian fantasy and the potentialities of the twenty-year-old Scientific Revolution in the sphere of warfare were

not even dreamt of. All these developments have completely revolutionised not only the technique and way of warfare, but the character of war as an instrument of policy.

Trend towards Scientific and Robot Warfare

The thirty-year period from the start of the First World War to the final stages of the Second World War can be regarded as a period of transition from industrialised warfare to scientific and robot warfare. The most significant developments of this period were the internal combustion engine—the period is sometimes called 'The Age of Oil'—and the radio. The first not only introduced entirely new means of achieving mobility on land by making possible movement over more or less any kind of terrain and hence *in any direction*, but it opened up for the first time a means of mobility—and a new battlefield—in the third dimension; radio, by providing a means of instantaneous transmission of the spoken word throughout the globe, opened up a new field of psychological warfare, an essential element in total war, and at the same time contributed a share towards the technological bases of automatic or robot warfare.

The object of war has always been to compel the enemy to bow to one's will. Until the advent of the aeroplane, this could only be done by overcoming the enemy's defensive barrier—his armed forces. The introduction of the air arm rendered this barrier largely ineffective. It was no longer necessary to tackle it when the moral and physical resistance of the enemy nation behind it could be *directly* attacked from the air and through the ether. In fact as air-power and the power of radio propaganda grew, the objective in warfare became less and less the enemy's armed forces, and more and more the enemy nation itself, its homes, its factories, its railways, its public buildings, its minds—in brief, its physical and moral resistance. This change is strikingly illustrated by the difference in the form of the last two world wars. No doubt, in the First World War the bulk of the population participated actively in the production of food and materials necessary to sustain the war effort; and in the blockaded countries it knew the hardships of famine. But the brunt of the battle was borne by the armed forces and, apart from a few unimportant air raids and a spectacular but ineffective performance of the Big Bertha, each country enjoyed behind its protective barrier complete immunity from actual warfare.

In the Second World War the brunt of the battle was borne by the civilian population—at least as far as the West was concerned. In fact, the first decisive battle of the war was the Battle of Britain, a battle in which neither armies nor navies played any significant part, as was later the case of the Battle of London and the Battle of the Ruhr.

Yet however great the contribution of aviation in the last war, the aerial arm never fulfilled Douhet's expectations—it did not prove decisive, in the sense that it *alone* could decide the issue of the conflict. The explanation can be found in the fact that true air-power appeared only in the latter stages of the war, and as its development was gradual it lost much of the strategic effect of surprise. The pressure of air-power was increased gradually and history shows that man has an almost infinite capacity for enduring physical and moral suffering as long as the process is gradual. Decisive results are produced far more frequently by sudden shocks than by protracted though increasing stress. Could the destruction wrought by air-power in twelve months have been compressed into a period of a few days or even a few weeks, it would in all probability have been decisive by itself. The attempts to bomb a nation into surrender, in the prevailing state of technique, proved much more difficult and costly than the early enthusiasts of air-power like Douhet and Mitchell had anticipated. The difficulty and the cost is brought home by the statement, made in 1944 by the British Secretary for War, that the labour devoted to the production of heavy bombers alone was equal to that allocated to the production of the whole equipment of the Army.

In this respect the flying bomb and the long-range rocket marked a great leap forward in the development of air-power, simply because they meant a great economy of labour and a vastly increased striking power. In another respect these two developments were truly revolutionary because they inaugurated a new era—the era of automatic or robot warfare.

Now the V1 and V2, as also the bomber, might well be regarded simply as a highly developed form of artillery. But there is a fundamental difference: artillery, because of its limited range, is primarily a tactical weapon for use in support of armed forces: the flying bomb and the long-range rocket, as well as the bomber, can be, and actually have been, used as independent strategic weapons, thanks to their range, which has already reached several thousand miles and promises to become global; and as such they tend to monopolise fighting by displacing not only all other weapons but also armies and navies. That is the real significance of robot warfare.

Yet all these new weapon developments were in a sense wanting; they involved improvements in range and speed, and derived but little from improvements in the power of explosives. Tremendously as it had risen, the destructive power of chemical explosives was not commensurate with the supersonic speed and the transcontinental range of the carrying devices. It needed the atom bomb to bridge the gulf, and the extent of this gulf can be gauged from the fact that the atom bomb multiplied overnight the already tremendous striking power of existing weapons by several hundred. In the Battle of Waterloo only 37 tons of shells were exchanged. The whole of the Boer War absorbed 2800 tons of explosives—about one night's bomb load in 1944. That is only slightly more than one atom bomb which, according to American calculations, is equivalent to 2100 tons made up of 400 tons of high explosive, 1200 tons of incendiaries and 500 tons of anti-personnel bombs—which is the load of 210 Superfortresses. But this comparison is in fact entirely misleading, for not even a raid of 1000 Superfortresses could have killed the 90,000 people at Hiroshima or the 40,000 at Nagasaki. The atom bomb, as used at Hiroshima and Nagasaki, is certainly not the last word in atomic weapons. In fact, the combination of atomic energy (both as a source of motive power and striking power) with robot devices, foreshadows weapons with a global range and a striking power which would enable mankind to commit suicide at will.

Now in contrast to earlier developments whose character is to be described as *technological*, all these new and revolutionary developments bear a distinctly *scientific*

character. Even as recently as the First World War the scientist was in the background, overshadowed by the engineer and the technician. In the Second World War the scientist definitely came to the fore, eclipsing the technician; for radar and atomic energy undoubtedly belong to the realm of science rather than to that of technology. The battle of the factories has been overshadowed by the battle of the laboratories. This evolution still further emphasises the principle in weapon production first expressed by Engels—that quality beats quantity; a principle the truth of which was strikingly illustrated by the Battle of Britain.

We have thus reached a crucial stage in an evolution which actually began nearly seven centuries ago. For the war of the laboratories is but the logical outcome of the new trend in warfare brought about by the introduction of gunpowder—the technological trend whose *leitmotif* is the gradual elimination of valour in favour of intellect, and today scientific and technical ability provides the most useful form of intellect. This process has gone so far that today it makes an anachronism of the concept of the Nation in Arms. Under the influence of scientific and technological developments, the Medieval Knight gave place to the professional army which in its turn gave place to the Nation in Arms. But today arms have become so scientific that they are bound to be sooner or later almost exclusively a matter for a small *élite*, a relatively much smaller body than the knights had ever been.

It may be argued that hitherto an antidote has always been found for every new weapon development, and that there is no reason why this should not be so of the atomic rocket, for example; that throughout history the pendulum of weapon development has swung alternately from the defence to the offence and back again, and that there is no reason why it should suddenly stop. But the argument is irrelevant. It is true that the cannon, which for a time monopolised fighting as a weapon of offence, was soon met by its antidote in the form of fortifications designed to subject the attacker to an effective cross-fire; it is true that the tremendous increase of fire-power brought about by the development of small-calibre automatic fire-arms—a wide sweep of the pendulum in favour of the defence—was answered by the introduction of bullet-proof armour which, in the form of armoured fighting vehicles, heavily loaded the dice in favour of the offensive; the menace of the bomber was parried by the development of the fighter and the improvement of ground defences that followed the introduction of radar aids. But all that did not prevent war from becoming more and more destructive. Moreover, the antidotes of the past never completely eliminated the danger, but only reduced it to manageable proportions. For example, anti-aircraft defence was effective if it succeeded in consistently destroying more than 10% of the attacking force, for when that figure was reached no air force could maintain large-scale attacks. But any counter-device short of the complete and absolute antidote—an ideal scarcely ever achieved in history—would be of little use in the case of weapons of saturation. Even if some defensive development of radar succeeded in eliminating 95% of the atomic missiles used, the 5% which reached their target would be capable of saturating it. In fact it is most unlikely that any effective antidote can be found against the weapons of saturation which science can produce at ever-decreasing cost. Indeed, the advent of atomic and biological weapons marks the first step towards discounting the value of quality or quantity in weapon production. For the striking power of these weapons is so devastating that beyond a certain point—the saturation point—an increase in quantity or an improvement in quality would be merely superfluous. Atomic power has brought this saturation point within practical reach.

Atomic War: Policy or Suicide?

But what form and character does war assume in the age of scientific and robot weapons?

The German military historian Delbrück was the first to point out in his *Geschichte der Kriegskunst* that, just as there were two forms of war—the limited and the unlimited, so there were two forms of strategy—the strategy of exhaustion and the strategy of annihilation. The first is exemplified most strikingly by Frederick the Great, the second by Napoleon. But the trend towards total war which was initiated by the French Revolution has made the strategy of exhaustion more and more impracticable, while the strategy of annihilation has come to be considered as the form of war natural to our civilisation.

Yet as long as unlimited aims had to make do with limited means, total warfare was a theoretical concept rather than a practical reality; and war still retained its purpose as an instrument of policy. It was only when science and technology made available more and more 'unlimited' means that the picture began to change drastically. For the tremendous increase in range and striking power, coupled with the unlimited aim, has gradually changed warfare from a fight into a process of systematic obliteration. Now in an industrial civilisation in which nations are economically interdependent, destruction, even if it is confined to the vanquished, is bound to dislocate the economy of the victor. Moreover, the unlimited exertions exacted by total war tax the victors to the point of ruin, as has been clearly shown by the last two wars. A third world war, waged with atomic robot weapons on both sides, would make it difficult to distinguish between victor and vanquished. Few people think otherwise, and these are mainly hopeful professional soldiers who, in their search for some means of defence against the wholesale destruction of atomic war, have already visualised a highly mobile form of warfare in which fully equipped armies would be dispatched in giant airships propelled by atomic energy and travelling at supersonic speeds with the object of occupying and disarming the enemy country.

Meanwhile we have to deal with realities. And the reality is that in the course of the last thirty years, war has become divorced from any objects of common-sense policy, and has degenerated into "a senseless thing without an object", an anachronism useless as a political tool. Since August 6, 1945, war has become suicide on a national or global scale. For if the object of war be acquisition of wealth it cannot be attained in an atomic war which destroys the wealth both of the victor and the vanquished.

The fact is that military means have reached an all-destroying power which is out of all proportion to any object consonant with common sense and self-interest. This is merely another way of saying that war in the age of science has definitely ceased to be an instrument of

[Cont. on p. 93

Botanical gardens are familiar to the public at large, who can appreciate the importance of these collections of living plants to the scientists, both pure and applied. No less vital to scientific progress are the culture collections used by the bacteriologist and the mycologist. In Britain the bacteriologist is better served than the mycologist in this connexion. The author of this article will be well-known to many readers for his book, *An Introduction to Industrial Mycology*.

Culture Collections are Indispensable

GEORGE SMITH, M.Sc., F.R.I.C.

SCIENTIFIC investigations on the nature or activities of almost all types of micro-organisms—bacteria, moulds, yeasts, Actinomycetes,* etc.—are greatly simplified if the organisms concerned can be grown in culture, and for some kinds of investigations cultures are a necessity. In the early days of Mycology, which is an older science than Bacteriology, cultural methods, as used at the present time, were unknown. Fungi were often described, as new genera and species, from specimens of uncertain age, and without an appreciation of all the changes which occur in the life-cycle of a fungus, changes which can usually best be studied by growing the organism under controlled conditions in the laboratory. Inevitably it happened all too frequently that two or more names were bestowed on what were merely different stages of the same fungus, thus laying up trouble for future generations of mycologists. Bacteriology was more fortunate in that suitable culture methods were devised whilst the science was in its infancy.

What is termed a 'pure culture' is a growth, or as it is often termed 'a colony', of a single species of organism, on a suitable culture medium, maintained under conditions which prevent its contamination by other species. In nature pure cultures are rare. Even when one organism is dominant, as in a typical case of bacterial infection or plant disease, other species are usually present, either growing very slowly or completely dormant. Various methods have been devised for separating mixtures of organisms as a preliminary to making pure cultures, but a description of these is outside the scope of this article. After this separation there are three requisites for obtaining satisfactory cultures.

1. A substance, or mixture of substances, on which the particular fungus or bacterium will grow readily and typically, must be chosen as culture medium.
2. This culture medium must be sterilised in order to kill all organisms originally present. Almost all suitable materials, as obtained for use, are heavily contaminated with bacteria, yeasts, and mould spores. The sterilisation is preferably carried out in the actual vessels to be used for the cultures, so as to minimise handling of the sterile material.
3. When the medium has been planted with the particular organism to be grown, some means must be adopted for preventing subsequent contamination.

The number of substances and mixtures of substances which have been used as culture media is enormous. The majority of the pathogenic bacteria are usually grown on a meat-extract medium, made neutral or very slightly alkaline, and often containing one or more special ingredients, such as sugars of various kinds, blood or serum. Many saprophytic bacteria grow well on the media used for fungi, or on extracts from the substances on which they are found in nature. The media used for fungi are usually slightly acid and include solid portions of plants, such as pieces of stems or tubers, extracts of various parts of plants, starch pastes, synthetical mixtures of salts and sugars, and, for fungi which normally grow on excrement, extracts of dung. Liquid extracts and synthetical solutions are used as such for special purposes, but, for normal use, are made into stiff jellies by the addition of 1·5–2% of agar-agar.

For making cultures to be stored in a culture collection, or to be sent from one laboratory to another, suitable quantities of culture medium are placed in hard glass test-tubes, which are then tightly plugged with non-absorbent cotton wool. The tubes with their contents are sterilised by steaming or, preferably in most cases, by cooking under pressure in an autoclave. It is usually advantageous to allow tubes which contain agar medium to cool in a sloping position, so as to give a large surface. The cotton wool plugs allow air to enter the tubes and gaseous products of metabolism to escape, but effectively filter the incoming air from bacteria and mould spores. Every time a tube is opened, for the purpose of sowing the medium with the organism to be grown or for transplanting from one tube to another, the mouth of the tube is heated in a flame in order to kill any stray organisms which might otherwise drift in; tools used for sowing, usually fine needles or wires with small terminal loops, are first heated in a flame to sterilise them.

All types of cultures become stale after a time, due to exhaustion of the medium and the accumulation of waste products of metabolism. It is necessary, therefore, if an organism is to be kept alive for any considerable period, to transplant at intervals, by transferring a tiny bit of growth from the old culture to a tube of fresh medium.

Anyone who studies micro-organisms keeps cultures of the species in which he is interested so long as the work is in progress. This is, of course, provided that the particular organisms can be grown in culture. Unfortunately there are many important micro-organisms, particularly amongst the parasitic fungi, which, so far, have never been grown in the laboratory, and which in consequence can be studied only in their natural habitats. There are very many small, more or less ephemeral, culture collections of this type. In addition, many teaching institutions maintain comparatively small collections to serve as types for the instruction of students.

* Actinomycetes are organisms which resemble fungi in forming mycelium but which in all other respects are more closely related to bacteria. The name means 'ray-fungi' and refers to their manner of growth. One species, *Actinomyces (Streptothrix) griseus*, produces streptomycin, one of the newest anti-bacterial agents.

FIG. 1.—Prof. Franz Král, born in Prague 1846, died in Prague 1911. Founder of the (the Král-Přibram collection in Vienna).

More ambitious are the collections amassed by taxonomists, that is by scientists who are interested in classification and who make an intensive study of particular groups of organisms with a view to assisting others to identify them. Such collections may contain anything from a few dozen to many hundreds of strains. They are seldom permanent, since sooner or later, after the specific taxonomic study is finished, the labour of maintaining a collection becomes irksome and without point. Fortunately many valuable private collections have been taken over by institutions which maintain permanent collections, but on the other hand some collections have been dispersed and lost to science.

Finally there are the national and international culture collections of a more permanent character, run on a semi-commercial basis, a number of which are described below.

The Value of Culture Collections

Apart from their value for teaching and for taxonomic purposes, the uses of private collections of cultures are many and varied. A number of firms and research laboratories, who are respectively interested in manufacturing or investigating the action of therapeutic substances, maintain collections of bacteria. New substances are first tested for their effect on different species of bacteria *in vitro*, that is for their effect on the growth of laboratory cultures of bacteria. Substances which, on the results of these tests, seem to be potentially useful are next tested for toxicity to animals, and finally laboratory animals are infected with various bacteria and the new drugs used in attempts to cure the diseases so produced.

Research institutions which investigate plant diseases maintain cultures of such of the causal organisms as can be grown. These cultures are used to test the resistance of plants specially bred or specially treated to resist infection. A number of research laboratories, both academic and industrial, which are interested in developing methods of control of mould growth on manufactured goods of various kinds, keep small collections of species of moulds which are known to attack particular types of materials. A fair number of institutions are carrying out research on the metabolism of micro-organisms, and here again collections of cultures are a necessity. For example, the largest collection of mould cultures in this country is maintained at The London School of Hygiene and Tropical Medicine for biochemical studies, and is constantly expanding as new aspects of fungal metabolism become of interest.

The purpose of the various national collections is rather different. They exist primarily to supply workers in the various fields of microbiology with correctly identified strains, often type strains of the original describers, of a wide assortment of cultivable organisms. They often take over private collections which can no longer be maintained by their original owners, in order to make the organisms available to others. These large collections are of unique value to taxonomists, and some of the institutions maintaining them employ a number of systematists who study important genera and publish bulletins and monographs which are of the greatest value to other scientific workers.

The first duty of the curator of a culture collection is to ensure that the organisms in his care are kept alive. This is not by any means as easy as would appear at first sight, for the food requirements of different species vary enormously. Some species thrive best on acid media, whilst others cannot tolerate the least trace of acidity; some can synthesise for themselves all, or nearly all, the various accessory factors (vitamins and substances related to them in their effect), and can therefore grow on simple media containing only salts and sugar, whilst other species must be supplied with a whole range of accessory factors; some will grow satisfactorily only when the concentration of nutrients in the culture medium is very low, whereas others prefer media containing large quantities of carbohydrates and can even tolerate high concentrations of salts. The requirements of a great many organisms are known with reasonable certainty, but occasionally new additions to a collection deteriorate and lose vitality on all the usual media, and ingenuity is taxed to find a really suitable substrate.

Even when there is no difficulty in maintaining vitality many organisms tend to change when kept for a long time in culture. Fungi lose their capacity for spore production, alter in biochemical characteristics, or produce mutants which swamp the parent strains; pathogenic bacteria tend to lose their virulence, this loss often being accompanied by changes in the appearance of colonies. This is perhaps the most serious problem connected with the maintenance of a culture collection, and there is, at present, no universal solution. With fungi, morphological changes can often be retarded or prevented by using several different culture

media in turn, including chiefly plant extracts and solid portions of plants, also by periodically plating-out (a method used for obtaining a large number of separate colonies from a fragment of a parent colony) and making fresh cultures from colonies which show maximum spore production. Other methods of retaining the original characteristics of cultures depend on reducing the frequency of sub-culturing. The length of time for which cultures will remain viable—that is, capable of yielding sub-cultures—varies much. Many bacteria must be sub-cultured at intervals of a few weeks or even more frequently, whilst cultures of most fungi will remain viable for several months or even several years. However, many bacteria and fungal spores will retain their vitality for longer periods if kept perfectly dry.

A method which has been used in some mycological laboratories for many years is to mix fungus spores with sand (which has previously been well washed, dried and sterilised in plugged tubes), dry *in vacuo* over phosphorus pentoxide, and then seal off the tubes below the plugs. When a fresh culture is required a tube is opened and a little of the sand sprinkled on to a culture medium.

Freeze-dried Spores

A more modern method, which is of proved value for the preservation of bacteria but which has only comparatively recently been adopted by mycologists, is the freeze-drying process.* A small portion of a bacterial colony, or a mass of fungus spores, is mixed, taking suitable aseptic precautions, with ox- or horse-serum. The suspension is distributed, in portions of about a tenth of a cubic centimetre, into plugged tubes 9-10 centimetres long and about 6 millimetres in bore. The tops of the plugs are burned off and the remaining portions pushed some way into the tubes. A number of such tubes are connected to a manifold and are then lowered into a bath at -40°C., where the serum is frozen almost instantaneously. The manifold is connected, through a water absorbent such as anhydrous calcium sulphate, to a high vacuum pump. The temperature of the bath is raised to -5° C. and maintained there until all the water has been evaporated from the suspensions in the tubes. The serum dries to whitish pellets of a chalky consistency. Finally the tubes, whilst still connected to the vacuum pump, are sealed off below the plugs by means of a blowpipe. When fresh cultures are required, the tube is scratched with a file, sterilised externally, and broken open. Specks of the dried material may be planted directly in ordinary culture tubes, or the pellet may be dispersed in a small volume of sterile fluid and drops of this used as inoculum for the new cultures. A number of disease-producing bacteria preserved in this way have not only remained viable for periods of many years, but have retained characteristics which are gradually lost in successive cultures made in the ordinary way at short intervals. Although it is too early, as yet, to say how long the spores of different species of fungi will remain alive when freeze-dried, there is no doubt that the method will be of value for the preservation of morphological and biochemical characteristics of species which tend to vary in culture, as, for example, the strains of *Penicillium notatum* used for the production of penicillin. Freeze-dried, or lyophile cultures as they are often called, are easily stored, since they are completely proof against accidental contamination, and can be dispatched from one laboratory to another with greater safety than ordinary cultures and, by air-mail at least, at much lower cost. (See Fig. 2.)

* See "Freeze-drying" in this month's PROGRESS OF SCIENCE.

Another problem of the worker in charge of a culture collection is that of contamination. Bacteria and spores of fungi are almost always present in the air and all too easily find their way into culture tubes when these have to be opened for any purpose. Sometimes, when a culture of one organism is invaded by another in this way, the two grow more or less side by side and the mixed nature of the culture is easily recognised. In this case it is usually not a difficult matter to separate the two and obtain anew a pure culture of the organism it is desired to keep. At other times the

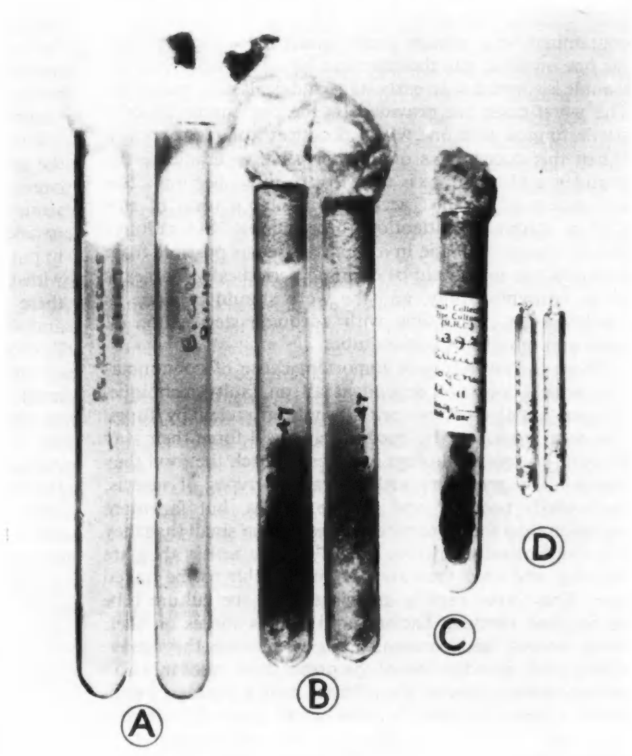


FIG. 2.—Comparison of cultures from different culture collections. *A.*—Bacterial cultures in $6 \times \frac{5}{8}$ in. tubes, standard in many laboratories. *B.*—Mould cultures in $5 \times \frac{5}{8}$ in. tubes; from the collection of The London School of Hygiene and Tropical Medicine. *C.*—Mould culture in $4 \times \frac{1}{2}$ in. tube, as sent out by the National Collection of Type Cultures. *D.*—Freeze-dried cultures from the American Type Culture Collection.

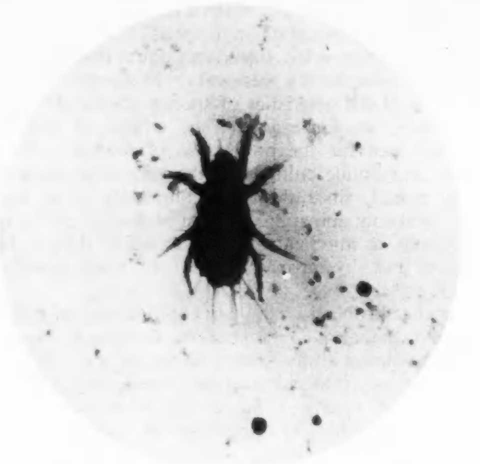


FIG. 3.—Adult mite in culture tube, as seen under a low power of the microscope (× 50). Mites are actually whitish, but show up dark by transmitted light.

contaminating organism grows much more rapidly than the one invaded, and the latter can be saved only when the trouble is spotted at an early stage and dealt with promptly. The worst cases are provided by the contamination of a sterile fungus with one which produces abundant spores. When this occurs it is often impossible to eradicate the intruder, and a culture is then lost to the collection. The best safeguard against accidental contamination of this kind is scrupulous attention to technique. Sub-cultures should always be made in a room as free as possible from draughts, the air should be cleansed periodically by means of an antiseptic spray, and the work should be done as quickly as is compatible with adequate sterilisation of tools and mouths of culture tubes.

There is, however, one important cause of contamination which does not depend at all on faulty technique. Various small creatures are strongly attracted by fungi, and to a less extent by bacteria, and will force their way through cotton-wool plugs in order to reach the food they desire. The predators include various types of insects, particularly psocids* and minute beetles, but far more common than these are mites. These are so small that they are indistinguishable from specks of dust unless they are moving, and even then are only just visible to the naked eye. They breed rapidly and pass from one culture tube to another, carrying bacteria and fungus spores on their hairy bodies, and contaminating every tube they enter. Often the first indication of the presence of mites in a collection is that some of the cultures have a peculiar moth-eaten appearance, but the presence of a number of contaminated cultures is a warning to examine these carefully under a low power of the microscope, when live mites and their eggs are readily detected. Fig. 3 shows a typical adult mite, as seen in a culture tube under the microscope. Mites can be killed, without harm to the cultures, by fumigation, the safest substance to use being paradichlorbenzene. Prevention, however, is better than cure,

* A family of small, soft-bodied insects related to book lice.

and there are several ways of effecting this, of which two are of particular interest. Storage of cultures at low temperature, about −4° C., is effective because it reduces enormously the speed of locomotion of the mites and prevents breeding, so that, if a few mites do gain access, their depredations are confined to the point of entry, and there is no wholesale contamination of cultures even when these are left unexamined for comparatively long periods. Storage at low temperature also has the advantage that it slows down growth of most fungi and bacteria, thus permitting of longer intervals between successive sub-culturings. The freeze-drying method of preserving cultures ensures, of course, absolute freedom from predators, since the culture tubes are hermetically sealed.

At the present time there are large culture collections in many different countries. The following descriptions cover only some of the oldest and best known of these, but should be sufficient to indicate the scope and typical organisation of such collections.

The Král-Přibram Collection.—Somewhere about the year 1900 (it has not been possible to ascertain the exact date) Král, a Czech, came to Vienna and opened a business for the sale of cultures of bacteria and micro-fungi. This was probably the first of the large-scale collections formed for the purpose of supplying cultures to workers all over the world. In addition to living cultures, Král supplied museum specimens in the shape of preserved and attractively mounted cultures, and photomicrographs of various organisms.

Král died in 1911 after a protracted illness, during which the collection was not properly cared for. It was taken over in 1913 by Přibram, who endeavoured to weed out strains which had deteriorated or become contaminated, to identify incorrectly named specimens, and generally to put the collection on a more satisfactory basis. However, with the development of the various national collections, there was naturally less demand for cultures from Vienna and the business gradually dwindled. It is now completely destroyed.

The Centraalbureau voor Schimmelcultures.—This, the most extensive collection of fungi in Europe, is situated at Baarn, in Northern Holland. As the Centraalstelle für Pilzculturen it was founded in 1903 by the International Association of Botanists, and was under the direction of the Dutch mycologist F. A. F. C. Went, in Utrecht. The original basis of the collection was a large number of cultures brought by Prof. Went from Java, but it was not until 1906 that an actual start was made with supplying cultures.

In 1907 a transfer was made to the Phytopathologische Laboratorium 'Willie Commelin Scholten' at Baarn, and the collection came under the direction of Prof. Joanna Westerdijk, who is still in charge. Soon afterwards it was decided to transfer all the yeasts and yeast-like fungi to Delft, where they came under the care of Prof. A. J. Kluyver. An attempt is made to include in the collection all species of fungi which can be grown in the laboratory, and the latest catalogue lists some 8000 species. A small charge is normally made for cultures. Whenever a mycologist describes a new species he receives a request from Baarn for a culture of the organism. In return he is entitled to receive a culture of any other fungus in which he may be interested, and can at any time be supplied with a culture

of his own species, if by chance he loses his original culture.

The mycologists at Baarn have themselves published descriptions of many new species and, in addition, have issued critical studies of various groups of moulds. Their most important taxonomic study, however, has been on the Yeasts and related fungi, the results being published in a three-volume monograph which is likely to remain for many years the standard work on the subject. It is very gratifying that this great collection came through the war practically unscathed. Maintenance of cultures was often difficult, but, in spite of shortage of materials for culture media and inadequate arrangements for sterilisation, very few of the strains were lost.

The American Type Culture Collection.—In 1911 there was established in New York a "Bacteriological Collection and Bureau for the Distribution of Bacterial Cultures", which issued its first catalogue, listing 350 species, in 1912. In 1925 the collection was taken over by the Division of Biology and Agriculture of the National Research Council, its name being changed to "The American Type Culture Collection". The fungi were placed under the care of Dr. Charles Thom in Washington D.C., whilst the remaining, and larger, part of the collection was housed at the John McCormick Institute in Chicago. In addition, arrangements were made to supply organisms belonging to certain groups from various private collections, such as Wakman's collection of Actinomycetes and Sherbakoff's collection of *Fusaria.* Later the fungi were transferred to the Bureau of Animal Industry, U.S. Department of Agriculture, still under the direction of Thom. Recently, on Thom's retirement, the collection of moulds was moved to the U.S. Department of Agriculture Northern Regional Research Laboratory at Peoria, Illinois, to come under the care of Dr. Kenneth B. Raper, who for a number of years had worked with Thom.

As in the case of the Centraalbureau at Baarn, the American Type Culture Collection has been the source of a number of extremely valuable taxonomic studies. From 1900 onwards Thom had been interested in the important and common genera *Aspergillus* and *Penicillium* and had published a series of papers clearing the ground for a more extensive study. In 1926 Thom, in collaboration with Miss Margaret B. Church, published the well-known monograph, *The Aspergilli*, a first-class piece of work which was of very great benefit to all students of moulds. In 1930 Thom's monograph, *The Penicillia*, appeared and, though it is not so satisfactory as the earlier monograph, it still remains the standard work on the taxonomy of this important but tantalising genus. Both books have long been out of print and yet the demand for authoritative works on micro-fungi is greater than at any previous time. The publication, in 1945, of Thom and Raper's book, *A Manual of the Aspergilli*, has brought the taxonomy of one genus up to date, but we are still awaiting a revision of the genus *Penicillium.*

The National Collection of Type Cultures.—This is the youngest of the large national collections of micro-organisms, dating only from 1920. In that year the National Collection of Type Cultures was founded under the joint control of the Medical Research Council, which finances administration and pays for items of special equipment, and the Lister Institute of Preventive Medicine, which houses and maintains the cultures. It was first under the direction of Sir John Ledingham, who was at the time Chief Bacteriologist at the Institute. In 1930 it came under the care of Dr. R. St. John Brooks, who continued to direct administration and expand the collection until the present year.

From the beginning the primary object of the National Collection of Type Cultures has been the maintenance and supply of cultures of pathogenic bacteria, and throughout its history its curators have been medical bacteriologists. Nevertheless, fungi were gradually added to the collection and, at the present time, comprise approximately half the total number of micro-organisms maintained in culture. Just as the American Type Culture Collection made arrangements for organisms of particular groups to be supplied from private collections, so our own National Collection of Type Cultures has listed a number of wood-rotting fungi, cultures of which are maintained at the Forest Products Research Laboratory at Princes Risborough. In addition the curator has been in touch with specialists all over the world, and hence has been able to obtain, for workers in this country, organisms not normally kept in the collection.

In view of the growing importance of fungi there is much to be said for splitting this collection and putting the fungi under the care of competent mycologists. In any case it is highly desirable that the collection of fungi be made more representative and that mycological taxonomists should not only be in charge of the fungi, but should be in a position to carry out systematic investigations. This country is much behind several others in the study of taxonomy and, as already pointed out, a large culture collection is the ideal place in which to carry out taxonomic investigations.

SCIENCE AND THE EVOLUTION OF WAR—*Continued from p. 88*

policy; that Clausewitz's conception of absolute warfare is simply not compatible with the absolute weapons of the atomic age.

Political and strategic thought has always had a pronounced tendency to lag behind the potentialities of science and technology. This tardiness was of little importance as long as scientific and technical progress was slow enough to allow time for adjustment. But the rhythm of scientific advance has today reached a dangerous pace: while the Age of Gunpowder endured for over four and a half centuries, the Age of Steam lasted only one century and a half and the Age of Oil extended over barely thirty years before it was superseded by the Age of Atomic Energy. Today there is hardly any respite for adjusting political and strategic thinking to the conditions created by science and technology. Science has undermined the foundations of nationalism at the very time when the creed of nationalism is at its strongest. Every scientific advance in the conquest of time and space makes an ever-widening breach in the bulwarks of nationalism and emphasises the need for political integration. For if, in the words of Professor Harold Urey, there is to be a next war fought with atom bombs, the one after that will be fought with bows and arrows.

Primer for an Atomic Age

For a long time we have thought it would be useful to print two reviews of every significant book on popular science, one by a layman who would be typical of half our readership, and the other by a scientist. The second number of Penguin's "Science News", devoted entirely to the subject of atomic energy, seemed to provide a good opportunity for trying out this idea.

A Layman's Critique

WILL this issue of *Science News*, designed for the 'general reader', find as many avid readers as that other Penguin, John Hersey's *Hiroshima*? It should, because it is at once the sober and factual companion to that piece of reporting and a generous shillingsworth of enlightenment on the principles and possibilities for good of nuclear discoveries. But it is only fair to say at once—as a 'general reader'—that it is not made over easy. True, there are exciting photographs to be referred to from time to time as one reads; and the story is logically assembled by the editors, so that we start by way of fascinating theory and work through the physics of fission and the bomb to the way ahead in medicine and so on (the use of tracers is an absorbing field on its own). Yet the layman, to whom vague school memories of Dalton, Mendeleyev and Rutherford, for example, give a willing but uncertain background, is soon startled by unexplained references to the work of named but unknown scientists. No doubt he should know all about these outstanding men: it is a sad truth that he does not. However, once started on this great subject, he does not give up. In the words of Mr. J. B. Priestley introducing a B.B.C. series of atomic lectures this month, he finds that there is 'no dodging' this subject of atomic power. Each chapter read makes it more essential to carry on to the next, and the going is not simple; the many experts of Los Alamos who contribute the various sections present him with a series of painstaking lectures which will be the undoubted delight of students, but they inevitably assume a quicker comprehension of each point, however tersely and logically developed, than is required of the general reader in most serious books. If this seems a harsh and ungrateful judgment in the eyes of the authors it may be added that anyone who really starts penetrating the solidity of this plain-covered and simply titled Penguin will read it all—and then re-read it for charity's sake. It is just the thought of those who will fall at the early hurdles that prompts this suggestion; that in works by experts for general readers the introduction, at least, might well be contributed by an informed non-expert, perhaps by a journalist specialising on scientific matters. Then the value of a comprehensive survey such as this, packed brilliantly nevertheless into small space (there are 168 pages, including an index cleverly arranged to act as a glossary as well, and an additional eight pages of photogravure illustration), might be increased. A final word should be said for the vital chapter on the bomb by Professor Philip Morrison; its simplicity and its warning are—if the understatement can be forgiven—dynamite.

J. A.

A Scientific Opinion

THIS is an excellent little book, and the first of its kind not to read like a watered-down version of the Smyth Report. This outstanding quality is probably due to the fact that the authors were not only connected with the development of the project but were all actually working at Los Alamos, where the first bomb itself was assembled. As a result they have been able to treat the subject in a semi-historical fashion, describing the course of both events and ideas during the development period, a method which helps considerably the understanding of the problems involved. For instance, the realisation that even after a pile had been successfully operated there was no certainty that a bomb could be exploded with any more violence than that of the conventional types of explosive, makes the distinction between fast and slow neutron chain reactions and the fundamental importance in the pile of the 'delayed neutrons' only too clear.

The articles by Peierls on Isotope Separation, Anderson on Plutonium Production and Morrison on The Physics of the Bomb, which form the greater part of the book, will for these reasons repay study by all who are interested in the technical aspects of the subject. The articles by Bethe and Frisch on Atoms and Nuclei and The Tools of the Nuclear Physicist provide a useful background of information, but have been necessarily over-condensed. The weakest part of the book is the article on Radioactive Tracers. Much more could have been made of this subject, and if space was the limiting factor the pages on detecting instruments, which are described elsewhere in the book, could have been omitted. Another aspect which is hardly mentioned, perhaps in this case because very little has been released on it, is radiation chemistry. The course of many chemical reactions is changed under the influence of various radiations, and the utilisation of these effects may be of very great importance in the future.

As a final criticism, but not to be construed as a deterrent to reading this book, it must be said that the editing is careless; there are needless repetitions, the Editorial Note refers to an article by title which does not appear in the list of contents. The illustrations could have been much better and more up to date.

C. G. A. H.

Science News No. 2. Edited by Professor R. E. Peierls and John Enogat. (Penguin Books, pp. 168, 1s.)

Far and Near

The World Federation of Scientific Workers

THE World Federation of Scientific Workers has appointed as Secretary-General designate, Mr. S. G. Crowther, the wartime director of the Science Department of the British Council.

A New Genetics Journal

OLIVER and Boyd Ltd., the Edinburgh publishers, announce a new journal of genetics which will be published three times a year. The title is *Heredity*, and the first number will appear in April. Editors are Dr. C. D. Darlington and Professor R. A. Fisher, with whom are collaborating Professor G. W. Beadle of the California Institute of Technology, Professor T. Caspersson of the Karolinska Institute, Stockholm, Professor T. Dobzhansky of Columbia University, Professor B. Ephrussi of Paris's Laboratorie de Génétique and Professor Ø. Winge of the Carlsberg Laboratorium, Copenhagen. The annual subscription costs £2 or $8, post free, and orders should be sent to the publishers at Tweeddale Court, High Street, Edinburgh.

Air Age World Map

AN 'air age' map of the world has been produced, which will be of interest to our readers. The best aid in seeing the modern world as a whole is a globe, but large-scale globes are expensive and are not portable; moreover only one-half of the globe can be seen at a time. This new map, produced by George Philip & Son, Ltd., is perhaps the most practical substitute for a globe that has yet been found. The map consists of fourteen sections printed on thin card, and represents global relations as faithfully as is possible using only flat surfaces. The scale is 1 : 39,500,000 (about 600 miles to the inch). The map costs half a guinea, and can be obtained through booksellers.

Restoration of Pulkovo Observatory

THE famous Pulkovo Observatory near Leningrad, centre of astronomical research in the Soviet Union was seriously damaged by German gunfire during the war. What is virtually a new observatory is being built there. The foundations of the new buildings have been laid, and the building itself is well under way. By the end of the summer scientific observations will be resumed, and the main building will be completed in 1948. The new observatory will be considerably larger than its predecessor, and will stand in a park of 400 acres. Houses are being built for the employees and scientific staff, and a guest house for visiting scientists.

Night Sky in April

The Moon.—Full moon occurs on April 5d 15h 28m U.T., and new moon on April 21d 04h 19m. The following conjunctions take place:

April				
8d 22h	Jupiter in conjunction with the moon,	Jupiter	0·6	N.
18d 06h	Venus	Venus	4	N.
19d 06h	Mercury	Mercury	2	N.
19d 07h	Mars	Mars	4	N.
27d 13h	Saturn	Saturn	4	S.

In addition to these conjunctions with the moon, Mercury is in conjunction with Mars on April 19d 23h., Mercury being 1·8 S.

The Planets.—Mercury rises about half an hour before sunrise on April 1, and can be seen in the eastern sky but will not be an easy object at that time. On April 15 the planet rises at 4h 44m, more than 1h 20m before the sun, and is then better placed for observation. It attains its greatest westerly elongation on April 5, and at the end of the month rises about ten minutes before the sun. Venus rises at 4h 40m, 4h 18m, and 3h 56m at the beginning, middle and end of the month, respectively, and is conspicuous as a morning star of stellar magnitude −3·5, the portion of the illuminated disc varying from 0·748 to 0·820. Mars is still too close to the sun to be favourably observed. Jupiter, in the constellation of Libra, rises at 22h 45m, 21h 42m, and 20h 35m at the beginning, middle and end of the month, respectively, and is easily recognised as an object of stellar magnitude −2. The distance of the planet from the earth varies between 434 and 411 million miles during April. Saturn, in the constellation of Cancer, is visible up to the early morning hours, setting at 3h 31m, 2h 37m, and 1h 40m, at the beginning, middle and end of the month respectively, and is brighter than a first magnitude star. During April the distance of Saturn from the earth varies between 809 and 853 million miles.

Amongst the spring constellations Virgo is conspicuous, and the bright star, Alpha Virginis, often known as Spica, can be easily found by joining Alpha and Gamma Urs. Maj. that is, the first and third stars in the Plough, and producing the line about seven times the distance between these two stars. This line will pass through Spica. It is about 180 light-years from the earth and is a close double star—so close that its companion is invisible in the telescope but has been detected by the spectroscope. The two stars are revolving rapidly round their common centre of gravity, completing a revolution in about four days, and their centres of gravity are separated by a little more than six million miles. If either or both of the components of Spica have a planetary system with intelligent life on any of the planets, then such life must be pitied. It would baffle the mathematician to predict the orbits in which the planets would revolve, because the presence of the star other than that around which the planets revolve would cause enormous disturbances to their orbits, and they would probably experience the greatest diversity in climate from extreme heat to intolerable cold. However, even if there were planets associated with Spica, it is very unlikely that they would develop high forms of life.

From April 18 to 22 the Lyrid meteors are active. If their paths are traced backwards they seem to converge to a small area near the constellation of Lyra.

Sir Henry Tizard.

The Government's Scientific Advisory Committee

THE Scientific Advisory Committee, which was set up during the war to advise the Government on scientific questions and which consisted of the officers of the Royal Society and heads of Government research organisations, has now ceased to exist. Its place is taken by two bodies, the Defence Research Policy Committee and the Advisory Council on Scientific Policy. Chairman of both is Sir Henry Tizard, who did so much during the two World Wars to secure the maximum application of science to the needs of the R.A.F.

Other members of the Advisory Council on Scientific Policy are: Sir Edward Appleton, Secretary, Dept. of Scientific and Industrial Research; Sir Alan Barlow, Treasury; Sir Howard Florey, Professor of Pathology, Oxford Univ.; Sir John Fryer, Secretary, Agricultural Research Council; Sir Claude Gibb, managing director, C. A. Parsons and Co., Newcastle-upon-Tyne; Sir Edward Mellanby, Secretary, Medical Research Council; Sir Edward Salisbury, Director, Royal Botanic Gardens, Kew, and Secretary, Royal Society; Sir Ewart Smith, Imperial Chemical Industries; Sir Reginald Stradling, Chief Scientific Adviser, Ministry of Works; Professor A. R. Todd, Professor of Organic Chemistry, Cambridge Univ.; Dr. A. E. Trueman, deputy chairman, University Grants Committee; Professor S. Zuckerman, Professor of Anatomy, Birmingham Univ.

The council which will be served by a small scientific secretariat in liaison with the secretariat of the Defence Research Policy Committee will advise the Lord President on matters relevant to official scientific policy on the civilian side.

Regional Conferences on Industrial Research

THE Federation of British Industries is sponsoring a series of regional conferences on industry and research. The first will be held at Birmingham on March 25. The principal speakers will be Sir Edward Appleton, F.R.S., Sir William Larke and Sir Peter Bennett, M.P. The conference is being held at the Queen's Hotel, admission free to all interested. Further information may be obtained from the F.B.I. Industrial Research Secretariat, 21 Tothill St., S.W.1.

A German Atomic Pile

AN interesting interview with Professor Heisenberg is recorded in *The Times* of February 24. According to this report Professor Heisenberg supervised all Germany's atomic research during the war, and he asserted in the interview that until June 1942 German achievements in this field equalled those of the United States. "But on June 6, we reported to the armaments minister, Speer, that atomic explosives could be produced either by the separation of the isotope from uranium or by building a uranium pile. But Hitler was a madly impatient man. We were asked how soon it would be possible to extract plutonium and we replied two years or longer. Hitler refused to consider any military measure that would take more than six months." As Germany lacked the industrial capacity to embark on U235 separation, "we went ahead with the uranium pile, having committed ourselves to nothing more than research into energy for machines", he added. Readers will find it useful to compare this statement with the one by Professor Hahn in DISCOVERY, April 1946.

A uranium pile was built at Haigerloch, consisting of two tons of uranium, two tons of heavy water and ten tons of graphite. Professor Heisenberg said in this connexion "As the world now knows, explosive plutonium is produced in such a pile." (Hahn stated that "we knew that an even heavier element of atomic weight 239 and atomic number 94 must exist *but we did not succeed in producing this substance.*")

In the same issue of *The Times*, Professor Heisenberg is reported as saying that the Russians offer 6000 roubles a month to any German atomic expert who will do research for the Soviet Government. He said he was promised in addition to his pay, fifty pounds of fresh meat a month, 3500 calories of food a day for each of his six children and a comfortable house. Although he declined the offer, three other German scientists accepted it. They were Professor Gustav Hertz, Dr. Robert Doepel and Dr. Ludwig Bevilogua, Heisenberg's assistant during the war.

According to the American journal *New Republic*, Heisenberg is to join the staff of Buenos Aires university.

UNESCO and Educational Rehabilitation

A CAMPAIGN to raise £25 million in money and materials is under way for the relief and rehabilitation of educational institutions in war-devastated countries. This was launched at a conference of thirty-two international voluntary organisations organised by UNESCO. When funds and materials are available, assistance will be offered to Belgium, Byelo-Russia, Burma, China, Czechoslovakia, France, Greece, Holland, Iran, Luxembourg, the Philippines, Poland, the Ukraine and Yugoslavia. It is hoped to continue to operate the Fellowship Training Scheme launched by UNRRA.

The American Chemical Society has just offered ten UNESCO scholarships of a total value of $25,000 for scholars, chemists and chemical engineers wishing to pursue advanced studies in the United States. Applicants must be prepared to spend at least two years working in their country of origin after the completion of their studies in the United States. Applications should be made to Dr. Joseph Needham, Natural Sciences Section, UNESCO, 19, Avenue Kleber, Paris, 16e.

New Director of Schools Broadcasting

MISS MARY SOMERVILLE, director of Schools Broadcasting, is retiring, and Mr. Richmond S. Postgate succeeds her. Mr. Richmond Postgate, who from 1939 to 1941 was assistant secretary to the Devon Education Committee, joined the B.B.C. in 1945 as Producer in the Services Educational Unit and last April was appointed assistant director of Schools Broadcasting.

Insects in Colour

THREE new Kodachrome films of interest to entomologists, agriculturists and general scientific audiences were recently shown in London. Their titles are:

Vegetable Insects (National Film Board of Canada, 16 mm., sound);

Colorado Beetle (Plant Protection Ltd., 16 mm., silent);

Control of Wireworms (Plant Protection Ltd., 16 mm., silent).

To quote the opening words of the commentary of the first of these films, "Insects are the most numerous of all living creatures". Setting aside the countless multitude of such microscopic forms of life as the Bacteria, this is an undisputed fact; and as so many species of insect are of the utmost economic and social importance to mankind, it is not a little surprising that the Class has been neglected for so long by the makers of serious films. Of films about insects there has been a fair average in the past, but the majority have been suitably dressed for the entertainment of the normal cinemagoer; few of them have been treated as serious subjects.

It is encouraging, therefore, to see an awakening interest in this aspect of science, both on the part of the makers of films, and on the part of firms whose business is the control of insect pests. It is gratifying, also, to note that colour is now deemed necessary for adequate presentation. In spite of its present limitations, colour adds a vitality to the subject, and a value far in excess of the glaring defects which are too often forced upon the consciousness of the discerning viewer.

Vegetable Insects—an unfortunate title—may be regarded as a general introduction to the control of insect pests in agriculture. The film suffers most from a plenitude of information. Visually it is a hotch-potch of widely contrasting scenes of vividly coloured insects and how to cope with them. It must present to the uninitiated a bewildering picture of an innumerable host of differing species, each of which is a potential menace to our food crops. On top of this, one is too often left in doubt as to the scale of the picture and the size of the insect shown. It is a pity that the makers of this film should not have curbed their enthusiasm for including as many examples of "the most numerous of all living creatures" as they could induce to perform in front of their camera; for instance, the scenes of the Praying Mantis, spectacular though they are, might well have been omitted. The commentary, too, is breathless, and so full that its content cannot possibly be assimilated at one sitting. Nevertheless, this film is a valuable contribution to the subject, and should provide a stimulating background for the agriculturist in his ceaseless fight against insect pests; it should prove, too, an admirable film for presentation to the audiences of scientific film societies and similar bodies.

The other two films have each a specific object, and they are the better for it. They fall into that much maligned category of the 'advertising film', but their content is such that this in no way detracts from their value.

In *Colorado Beetle* the origin and spread of the pest is depicted, and the life history of the beetle is shown in sufficient detail for the purpose of the film. The serious outbreak of the pest in the potato fields of Jersey, the elaborate planning of 'Operation Beetle', and the energetic methods adopted to stamp it out provide admirable subject matter for the remainder of the film.

Control of Wireworms has less spectacular material upon which to draw. Nevertheless it is a competent exposition of a very real problem to the farmer, particularly in these days of the extensive ploughing of new ground. The life history of the insect is somewhat briefly dismissed, to be followed by an indication of the normal methods of field survey and cultural control. The 'meat' of the film, however, is the efficacy of 'Gammexane' as a control for wireworm, and the practical methods of its application. With this in mind, one can perhaps forgive the makers their inclusion of material irrelevant to the main theme such as the control of apple blossom weevil and other pests by means of 'Gammexane'.

The two films are silent, with captions. A small criticism is that the captions would have been better without factual backgrounds; a more serious criticism is that, as these films are described as being "designed for showing with a commentary" to be delivered *ad lib* by a technical expert, there should have been no captions. Inevitably the speaker from time to time overlaps the captions with his remarks, and the audience becomes baffled and bemused in its efforts both to read the printed word and to follow the spoken word simultaneously.

The filming of insects is a tricky job and continually calls for the exercise of considerable ingenuity; colour adds problems which have yet to be solved. A large measure of success has attended the efforts of the Plant Protection cameraman, but his Canadian counterpart still has more to learn about the lighting of very small subjects for colour. With, as yet, no firm criteria by which to judge colour films of entomological subjects, one can hazard the opinion that the general level of photography in all these productions is high.—J. V. DURDEN, A.R.C.S., B.Sc.

(*This review is contributed by arrangement with the Scientific Film Association.*)

Progress of Food Yeast Manufacture

MANY months ago it was announced that a food yeast plant was to be erected at Frome in Jamaica, and this was intended to be a prototype of similar factories which would make available food yeast as a dietary supplement in places where conditions of malnutrition existed alongside accumulations of carbohydrate wastes and by-products. Since the original announcement there has been virtually no news as to how the project was developing, and there has been criticism at the apparent lack of progress. The January issue of *Food Manufacture* contains the report of an interview with Dr. A. C. Thaysen, who was associated with the pilot-plant trials of food yeast manufacture at the Chemical Research Laboratory on which the design of the factory in Jamaica was based. It goes some way towards explaining the delay in producing food yeast at Frome. One of the first points made by Dr. Thaysen is that the increase in the price of molasses, the raw material for the process, has falsified early estimates of the price at which food yeast could be sold, he says that the price must now be put at between 6*d*. and 1*s*. a pound.

From Dr. Thaysen's description it seems that stainless steel was not used for certain vital parts of the plant and this has led to contamination of the yeast with iron which reduces yield. There is insufficient aeration in the fermenter and more air compressors will have to be added. When these adjustments have been made, output is expected to reach 12–15 tons a day, based on 50–60 tons of molasses. The high price of molasses has increased the attraction of other raw materials. Perfectly good food yeast has been prepared from waste potatoes, bananas and other fruits, carob beans, straw and even sulphite lyes. But where the raw material is starchy it is necessary to convert the polysaccharide into glucose—yeast cannot utilise starch—and this conversion adds to production costs.

Printed and published in Great Britain by Jarrold & Sons, Ltd., The Empire Press, Norwich.

cribed as being
with a com-
d *ad lib* by a
ould have been
e speaker from
captions with
lience becomes
efforts both to
d to follow the
ly.

tricky job and
xercise of con-
adds problems
lved. A large
attended the
ection camera-
ounterpart still
the lighting of
lour. With, as
which to judge
gical subjects,
nion that the
hy in all these
V. DURDEN,

ed by arrange-
m Association.)

anufacture

nounced that a
be erected at
s was intended
milar factories
e food yeast as
ces where con-
isted alongside
rate wastes and
ginal announce-
ually no news
developing, and
t the apparent
nuary issue of
s the report of
. Thaysen, who
ot-plant trials of
t the Chemical
hich the design
ca was based.
explaining the
east at Frome.
made by Dr.
se in the price
aterial for the
y estimates of
st could be sold,
ist now be put
ound.

description it
as not used for
plant and this
f the yeast with
eld. There is
the fermenter
s will have to
justments have
ected to reach
n 50–60 tons of
of molasses has
of other raw
food yeast has
aste potatoes,
, carob beans,
yes. But where
y it is necessary
ide into glucose
arch—and this
ction costs.